remote sensing

MDPI

Article

Night-Time Light Remote Sensing Mapping: Construction and Analysis of Ethnic Minority Development Index

Fei Zhao [1,2], Lu Song [1], Zhiyan Peng [1], Jianqin Yang [3], Guize Luan [1], Chen Chu [1], Jieyu Ding [4], Siwen Feng [5], Yuhang Jing [1] and Zhiqiang Xie [1,2,*]

1 School of Earth Sciences, Yunnan University, Kunming 650500, China; cartographer@ynu.edu.cn (F.Z.); songlu@mail.ynu.edu.cn (L.S.); pengzy834@mail.ynu.edu.cn (Z.P.); luanguize@mail.ynu.edu.cn (G.L.); chuchen2017@mail.ynu.edu.cn (C.C.); yuhang@mail.ynu.edu.cn (Y.J.)
2 Engineering Research Center of Domestic High-Resolution Satellite Remote Sensing Geology for Universities of Yunnan Province, Kunming 650500, China
3 Kunming Municipal People's Congress Standing Committee, Kunming 650500, China; yjqshe@163.com
4 School of Resources and Environmental Science, Wuhan University, Wuhan 430079, China; jadeding@whu.edu.cn
5 Institute of International Rivers and Eco-Security, Yunnan University, Kunming 650500, China; fengsiwen1004@mail.ynu.edu.cn
* Correspondence: xzq_2019@ynu.edu.cn

Abstract: Using toponym data, population data, and night-time light data, we visualized the development index of the Yi, Wa, Zhuang, Naxi, Hani, and Dai ethnic groups on ArcGIS as well as the distribution of 25 ethnic minorities in the study area. First, we extracted the toponym data of 25 ethnic minorities in the study area, combined with night-time light data and the population proportion data of each ethnic group, then we obtained the development index of each ethnic group in the study area. We compared the development indexes of the Yi, Wa, Zhuang, Naxi, Hani, and Dai ethnic groups with higher development indexes. The results show that the Yi nationality's development index was the highest, reaching 28.86 (with two decimal places), and the Dai nationality's development index was the lowest (15.22). The areas with the highest minority development index were concentrated in the core area of the minority development, and the size varied with the minority's distance. According to the distribution of ethnic minorities, we found that the Yi ethnic group was distributed in almost the entire study area, while other ethnic minorities had obvious geographical distribution characteristics, and there were multiple ethnic minorities living together. This research is of great significance to the cultural protection of ethnic minorities, the development of ethnic minorities, and the remote sensing mapping of lights at night.

Keywords: night-time light remote sensing; ethnic minorities; core ethnic minority areas; development index; toponym data

Citation: Zhao, F.; Song, L.; Peng, Z.; Yang, J.; Luan, G.; Chu, C.; Ding, J.; Feng, S.; Jing, Y.; Xie, Z. Night-Time Light Remote Sensing Mapping: Construction and Analysis of Ethnic Minority Development Index. *Remote Sens.* **2021**, *13*, 2129. https://doi.org/10.3390/rs13112129

Academic Editors: Ran Goldblatt, Steven Louis Rubinyi and Hogeun Park

Received: 22 April 2021
Accepted: 27 May 2021
Published: 28 May 2021

1. Introduction

Ethnic minorities refer to ethnic groups other than the main ethnic group in a multi-ethnic country. The proportion of their population is smaller than that of the main ethnic group. There are currently more than 2000 ethnic groups in the world, and the total number of Asian ethnic groups is more than 1000, accounting for about half of the total number of ethnic groups in the world. Among them, the total number of ethnic groups in China, India, the Philippines, and Indonesia exceeds 50. There are about 170 ethnic groups in Europe, and there are about 20 basically single-ethnic countries. There are 55 ethnic minorities in China except for the main ethnic group. The distribution of ethnic minorities in China is relatively wide, mainly showing the distribution of "large mixed residences and small settlements". The indicators to measure the development level of a region include education level [1], regional GDP [2–4], population [5,6], poverty index [7], etc. Among them, the most direct and quantifiable one is economic development. The most direct connection between a

nation and a country is the consistency of economic interests [8]. The distribution of ethnic minorities is different, their ecological environment, cultural diversity (such as living habits, languages, religious beliefs, etc.), the technology used in production, the allocation of resources is different, so their economic development is also different [9]. The economic development of ethnic minorities is part of the country's economic development and contributes to the economic development of the entire country. If there is a problem with the economic development of ethnic minorities, it will directly affect the country's economic development to a certain extent. Due to differences in living environment and life concepts, there are different economic development models in economic development, leading to better ethnic development in some places and poorer ethnic development in other places. However, the economic development of China's ethnic minority areas is generally unbalanced. China is a multi-ethnic country, and the common development and mutual assistance of all ethnic groups can make our country stronger and more prosperous. However, due to the different levels of economic development of different ethnic groups, studying the development of ethnic minorities plays an important role in formulating and adjusting corresponding policies. It is very important to understand and discover the development status of each ethnic group. This study helps to understand the development status of ethnic minorities through a simple and quick method.

At present, it mainly studies the economic development index of ethnic minorities from gross domestic product (GDP). A study of the economic development status of the five western ethnic autonomous regions in Inner Mongolia, Guangxi, Tibet, Ningxia, and Xinjiang found that the GDP of the five ethnic minorities regions lagged behind the national level, and there were also significant differences in the economic development level of ethnic minorities in the prefectures regions. The urban–rural per capita income ratio exceeded 2.5:1, and the highest urban–rural per capita income ratio reached 5.6:1, which far exceeded the international standard (according to the general international situation, the per capita GDP is between US$800 and US$1000, and the urban–rural per capita income ratio is 1.7:1 or so) [10]. Li [11] found that the income gap between urban and rural areas in ethnic minorities regions is large, as was the gap between GDP and the national level. The absolute difference in the per capita GDP of the ethnic minorities in Northwest China is gradually expanding, and the absolute difference in the economic development level of the ethnic minorities is expanding [12,13]. Zheng [14] pointed out in his research that both in terms of innovation and economic development, ethnic minority areas lagged behind the national level, and there were large differences in economic development among ethnic minority areas. Luo and Zhuang [15] conducted research on the economic development of the two provinces of Guangxi and Yunnan in the past 15 years, and found that the higher the proportion of the minority population in the total population, the lower the economic development level of the county-level region. Although there are many studies on the development of ethnic minorities, there are very few studies on the development index of ethnic minorities, and the research on the GDP of ethnic minorities only stays at the level of statistical yearbook research and qualitative analysis. The use of more scientific methods to study the development index of ethnic minority regions is of reference significance for understanding the development of ethnic minority regions, the development differences of various ethnic minorities, and the state's formulation of corresponding policies.

Night-time light data refer to the capture of town lights, fishery lights, etc. at night without clouds [16]. The currently widely used night-time light data include: (1) The Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS) satellite, which provides data from 1992 to 2013; (2) The Suomi National Polar-Orbiting Partnership's Visible Infrared Imaging Radiometer Suite (NPP-VIIRS), which provides data from 2012 to the present; and (3) China's first professional night-time light remote sensing satellite "Luojia-1", jointly developed and produced by the Wuhan University team and related institutions, which provides data from 2018 to the present.

The level of human activities and economic development can be better reflected by night-time light remote sensing data, so it is widely used in social and economic

fields [17–19] such as economic activity monitoring [20] and economic development research [21]. Doll et al. [22] used night-time light data to assess socio-economic development and found that it was highly correlated with GDP on a national scale (R^2 = 0.85, when R^2 is greater than 0.8, it can be considered that the two variables are highly correlated), and simulated the spatial distribution of GDP. Elvidge et al. [23] used DMSP-OLS data to analyze the relationship between night lighting area and GDP in 200 countries and found that there was a good linear relationship between night-time light area and GDP. Henderson et al. [24] used a DMSP stabilized light source and radiometric correction images, which correctly reflected the differences in the social and economic development levels of San Francisco, Beijing, and Lhasa. Henderson et al. [25] found that the brightness of night lights in a country had an obvious linear relationship (R^2 = 0.8) with the country's GDP development level. Michalopoulos et al. [26] used a similar method (similar to Henderson et al.) to study the correlation between night-time light data and GDP in Africa, and got good results. Wu et al. [27] used DMSP-OLS data to estimate GDP and the results were satisfactory. Jiang et al. [28] used DMSP-OLS data and NPP-VIIRS data to perform regression simulations on multiple socio-economic parameters, and found that using NPP-VIIRS night-time light data to regress with the whole city's GDP, R^2 reached 0.9102. This proves that night-time light data have a good linear correlation with GDP and power consumption, and found that NPP-VIIRS had higher accuracy and more advantages. Zhu et al. [29] found that compared with traditional socio-economic indicators (GDP, oil and gas production, etc.), night light data are more sensitive and more intuitively reflects social and economic development.

Some scholars have also used night-time light data to study the poverty index of a region. This method can also reflect the development status of the region to a certain extent. Li et al. [30] used the method of machine learning, combined with the robust features of the night light image spatial characteristics to identify China's high-poor counties. The overall accuracy of the results was greater than 82%, and the user accuracy was greater than 63%. Andreano et al. [31] used DMSP-OLS data to perform spatial classification and continuous time estimation of poverty gap, number of people, and Gini index in 20 Latin American and Caribbean countries. It was found that combining night-time light data helped to better understand poverty and its temporal and spatial dynamics. Pokhriyal et al. [32] used environmental data and call data records to accurately predict the global multidimensional poverty index. This method has high accuracy in predicting health, education, and living standards (Pearson's correlation coefficient is 0.84–0.86). Li et al. [33] used the principal component analysis method to establish a comprehensive multi-dimensional poverty index, and showed the temporal and spatial heterogeneity of multi-dimensional poverty in 2311 counties in China. It was found that the mountainous areas of Southwest, North China, Northwest China, and the plateau areas of Southeast China had higher levels of economic development.

A large number of studies have proven that the night-time light data reflect the development level of a region, so it is feasible to use it to construct a development index. Compared with traditional statistical yearbook research and qualitative analysis, this paper used night-time light data to construct the development index of ethnic minority areas, which is more accurate and saves resources.

2. Materials and Methods

2.1. Materials

2.1.1. Study Area

Yunnan Province is located on the border of southwestern China. Its geographic location is between 21°8′–29°15′ N and 97°31′–106°11′ E. Yunnan Province is the province with the largest number of ethnic minorities in China. According to the statistics of the sixth national census in 2010, there are 25 ethnic minorities in Yunnan Province, among which the population of Yi, Bai, and Dai are larger. Among the 25 ethnic minorities in Yunnan Province, 15 ethnic minorities are unique to Yunnan such as the Bai, Hani, Lisu, Dulong, etc.

The development of ethnic minorities in Yunnan Province has made great contributions to the socio-economic development of the entire Yunnan Province. Yunnan Province is a mountainous plateau. Compared with provinces in plain areas, its topographic features are unfavorable for its development. However, at the same time, Yunnan Province is located on the border of southwest China and is a key area for the development of the "Belt and Road" initiative. There are 16 prefecture-level administrative regions in Yunnan Province including eight prefecture-level cities, eight autonomous prefectures, 17 county-level cities, and 129 county-level districts. Among the 16 prefecture-level administrative regions, there are eight ethnic minority core areas. The administrative division and specific geographical location of Yunnan Province are shown in Figure 1.

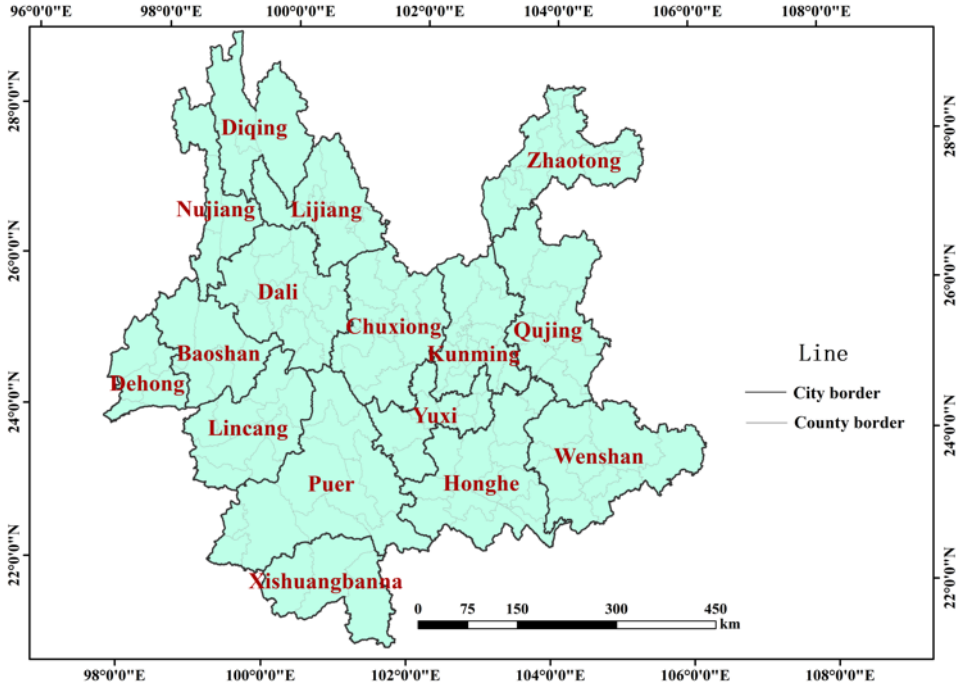

Figure 1. Geographical location and administrative boundaries of Yunnan Province.

2.1.2. Data Sources

The data used in this article are as follows (Table 1): (1) NPP-VIIRS composite data; (2) toponym data; (3) Yunnan Province census statistics; (4) Yunnan Province county level Administrative division boundaries; and (5) Yunnan Statistical Yearbook Data.

Table 1. Details of the data sources in this study.

Data	Data Information	Year	Source
NPP-VIIRS	NPP-VIIRS cloudless DNB compound monthly average data	2018	Earth Observation Group (EOG) (https://eogdata.mines.edu/download_dnb_composites.html, accessed on 28 May 2020)
Toponym	Results of the Second National Toponymic Census of China	2019	China National Geographical Names Database (http://dmfw.mca.gov.cn/, accessed on 20 May 2020)
Statistics of Yunnan Province Census	Data from the Sixth Census of Yunnan Province	2010	China Social Big Data Research Platform (http://data.cnki.net/, accessed on 14 June 2020)
Boundaries of county-level administrative divisions in Yunnan Province	County-level vector data in Yunnan Province	2017	National Basic Geographic Information Center (http://www.ngcc.cn/ngcc/, accessed on 13 May 2019)
Yunnan Statistical Yearbook Data	Socio-economic indicators of Yunnan Province	2013–2018	People's Government of Yunnan Province (www.yn.gov.cn, accessed on 2 May 2021)

The NPP-VIIRS night-time light data adopt the monthly average data of the global cloudless Day–Night Band (DNB) composite data in 2018, and the spatial resolution of NPP-VIIRS data is 500 m. Studies have shown that the DNB of the NPP satellite system is widely used to estimate social and economic parameters, and the in-orbit radiation correction can improve data quality [34,35]. Finally, monthly average data were used to synthesize annual average data for research. The data were downloaded from the Earth Observation Group (EOG) (https://eogdata.mines.edu/download_dnb_composites.html, accessed on 28 May 2020).

The toponym data used in the study come from the results of the second national toponym data census, which mainly includes the meaning of toponyms, that is, the ethnic types of toponyms, the feature type of toponyms, the historical sources of toponyms, the spatial location, and other information, which can be downloaded from the China National Geographical Names Information Database (http://dmfw.mca.gov.cn/, accessed on 20 May 2020).

The census statistics of Yunnan Province use the data of the sixth national census, and the data can be downloaded from the sixth census data of Yunnan Province on the China Social Big Data Research Platform (http://data.cnki.net/, accessed on 14 June 2020). In the data, detailed statistics are made on the population of all ethnic groups in the county-level regions of Yunnan Province.

The county-level administrative divisions of Yunnan Province are derived from the 1:4 million vector data provided by the National Basic Geographic Information Center. In order to make the research more convenient, all the data in this paper were converted into the Lambert projection (Asia_Lambert_Conformal_Conic) based on WGS_1984. In order to make the research more accurate, combined with the geographic location of the study area, the central meridian was set to 102°, the first standard latitude was 22°, and the second standard latitude was 28.3°.

The statistical yearbook data contain a large amount of socio-economic data such as regional GDP per capita, regional total GDP, and regional employees. The development data and production methods of a region can be obtained from the statistical yearbook. The statistical yearbook data of Yunnan Province from 2013 to 2018 was used to verify the feasibility of the method in this paper.

2.2. Methods

Using the 2018 NPP-VIIRS night-time light data to construct the Yunnan Minority Development Index requires the following three steps. First, preprocess the downloaded NPP-VIIRS cloudless DNB composite monthly average data to obtain stable night light data. Second, extract the toponym data that contain minority information in the toponym data to obtain the Yunnan Province minority toponym dataset, and conduct a kernel density analysis on each type of ethnic minority toponym data in Yunnan Province. Calculate the minority development index using the results of kernel density analysis combined with the results of the minority population proportion grid results and the NPP-VIIRS night-time light data. Finally, in order to more clearly reflect the distribution of ethnic minorities, combine the toponym data and the results of the minority development index to obtain the research area distribution of 25 ethnic minorities. The specific process is shown in Figure 2.

2.2.1. NPP-VIIRS Data Preprocessing

In order to avoid the influence of grid deformation, sensors, and other factors on the research results, first, geometric correction was performed on the 2018 NPP-VIIRS monthly cloudless DNB composite data using the geometric correction tool in ENVI. Since the geographic coordinate system of the acquired NPP-VIIRS data is WGS_1984, set the projection parameter to the WGS_1984 geographic coordinate system, set the output pixel size to 1000 m, and select the cubic convolution method as the resampling method. The NPP-VIIRS night-time light data obtained include fires, aurora, and other noises. Therefore, it needs to be radiated to eliminate the influence of background noise. The process of

radiant correction can be referred to in [36]. Load the data to be corrected in ENVI and use the RPC orthorectification workflow tool for correction. First, select the average radiance value of the cloud in the low reflectivity area of the sea surface as the calibration value for removing scattered light, and then subtract the calibration value from the entire image to remove the cloud scattering. Second, using the method of adjacent aberrations, a threshold was set to obtain a stable surface area, and the obtained stable surface area was used as a mask, and the radiation value of the mask area was statistically analyzed. Finally, three times the average radiation value of the statistical analysis was taken as the confidence interval to remove the surface scattered light. After radiant correction, effective night-time light data can be obtained. Then, use the data after geometric correction and radiometric correction to synthesize the 2018 annual average data. The calculation formula is:

$$DN_j = \frac{\sum_{i=1}^{12} DN_i}{12}, \quad (1)$$

where DN_i represents the light brightness value in month i, and DN_j represents the average light brightness value in year j.

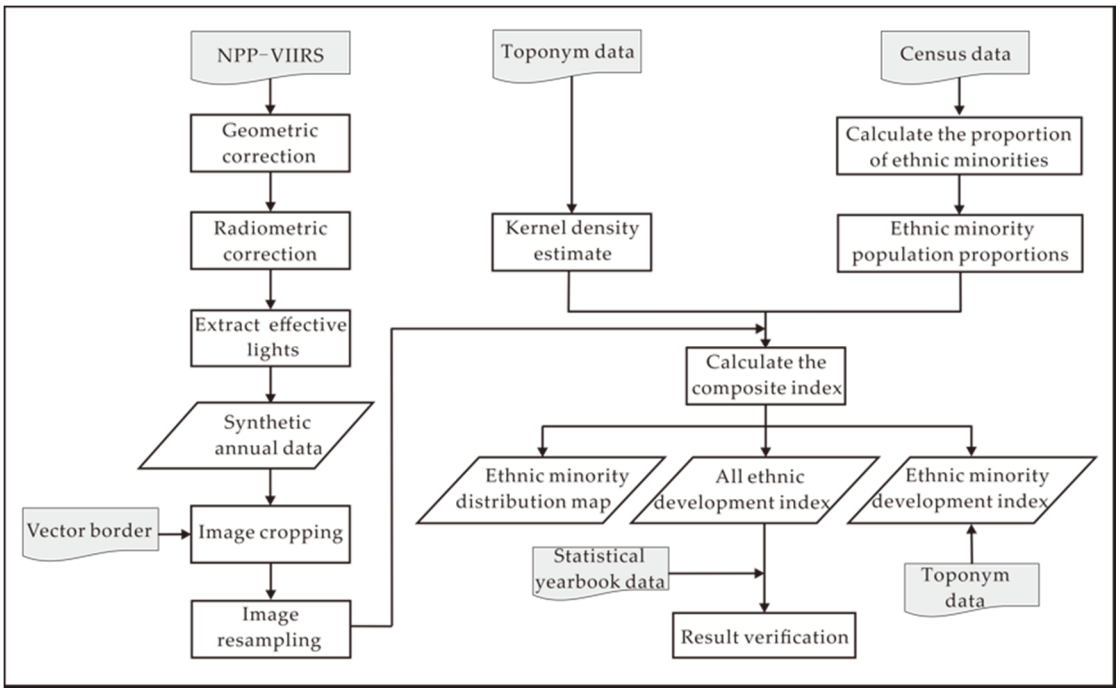

Figure 2. Flowchart of the methodology.

After synthesizing the 2018 NPP-VIIRS annual data, we used the administrative divisions of Yunnan Province as a mask to trim the night-time light data to obtain the study area. In order to make subsequent research more convenient, the coordinates were unified into the Lambert projection based on WGS_1984. Finally, using the cubic convolution interpolation method to resample the NPP-VIIRS data to a grid size from the original pixel size of 500 m × 500 m to 1000 m × 1000 m, and obtained stable night light data in 2018. The results are shown in Figure 3.

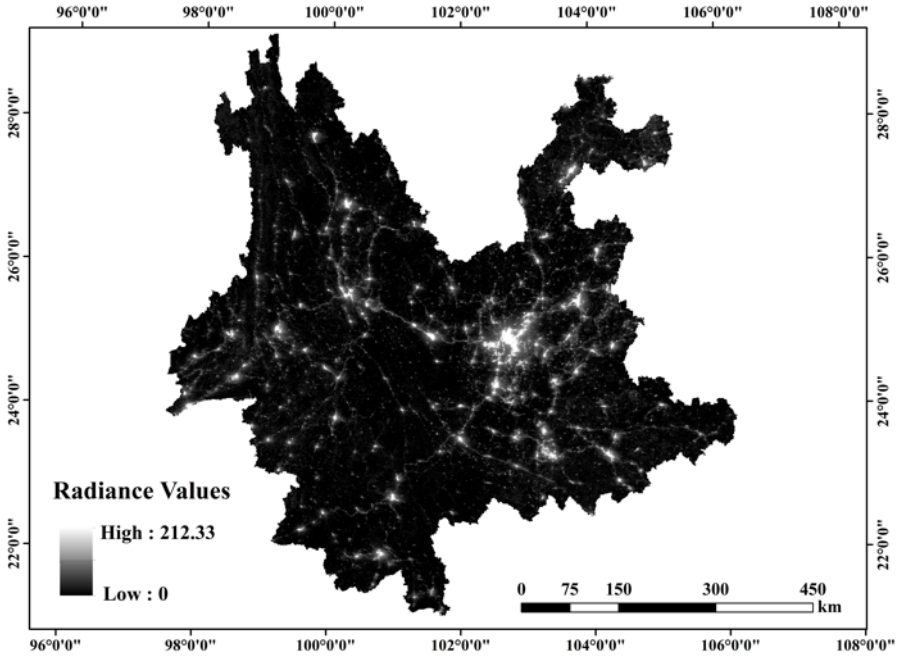

Figure 3. Data processing results of NPP-VIIRS in 2018.

2.2.2. Construction of the Development Index of Various Ethnic Minorities

Gelling stated that toponyms are "road signs to understand the past" [37] as toponyms are used to indicate the names of specific geographic areas and contain rich information such as the ethnic type of the local residents and the interpretation of the geographical environment by local people at the time of naming [38,39]. Studying toponyms is the basis for understanding the national culture and local characteristics of a region [40]. From toponym data, the ethnic types, language and culture, and religious beliefs of a region [41], spatial location, and the environmental evolution process related to history [42,43], environment, and landforms [44] can be extracted. This is of great significance for understanding ethnic minority settlements and the distribution of ethnic minorities.

The national census is a census about the population of the whole country. The contents of the census mainly include gender, age, ethnicity, etc. The subjects of the census are mainly natural persons living in the People's Republic of China (except Hong Kong, Macau, and Taiwan). From the census data, information about ethnic minorities can be extracted such as the place of residence of the ethnic minority population, and information about the proportion of the ethnic minority population can also be further extracted.

The distribution of ethnic minorities in China mainly shows the distribution of "large mixed residences and small settlements". Therefore, the toponym of ethnic minorities will be unevenly distributed, and the toponym data obtained are discrete measured values. Kernel density estimation (KDE) is used to calculate the unit density of the measured value of point and line elements within a specified area. It can intuitively reflect the distribution of discrete measured values in a continuous area. Kernel density estimation can obtain the weighted average density of all data points in the study area [45]. The weight assigned is related to the distance of the center point of the data point. The farther away from the center point, the smaller the weight is assigned, and vice versa [46]. The formula for calculating the kernel density P_i at any point i in space is:

$$P_i = \frac{1}{n\pi R^2} \times \sum_{j=1}^{n} K_j \left(1 - \frac{D_{ij}^2}{R^2}\right)^2, \quad (2)$$

where R is the search radius (bandwidth) of the selected area ($D_{ij} < R$); K_j is the weight of the research data point j; D_{ij} is the distance between the space point i and the research data

point *j*; and n is the number of research data points *j* within the search radius *R*. The search radius *R* has a direct impact on the results of kernel density analysis [47].

In this study, 25 ethnic minority geographic names were used for kernel density analysis. Because the area of an ethnic minority gathering area in the study area is about one square kilometer. According to this feature, through comparative analysis, the search radius of kernel density estimation is constantly changed, and finally, it was found that when the search radius was 1000 m, the effect was better, and can distinguish ethnic minority gathering areas. Considering that there are places with ethnic minority toponyms, but no ethnic minorities living in them, this paper used census data to calculate the proportion of 25 ethnic minorities in the study area, and obtained a grid map of the proportion of 25 ethnic minorities for future use.

The development of a region or a nation is often affected by many factors such as population, economy, environment, geographical location, etc. In addition, there are differences in the development of different regions of the same ethnic group and between different ethnic groups in the same region. Therefore, it is necessary to construct a development index that can reflect this difference in order to quantitatively analyze the development of ethnic minorities. This article used population, toponym data, and NPP-VIIRS data combined with the literature [48,49] as well as the formula form of the spatialization of population data to propose a method to calculate the development index of various ethnic minorities. The calculation formula is shown in Equation (3):

$$CPS_i = \sqrt{PR_i \times KDE_i \times NPP_i} \quad (3)$$

where CPS_i is the development index of minority i; PR_i is the population proportion of minority i; KDE_i is the kernel density analysis result of minority i; and NPP_i is the night light radiance value of minority i.

2.2.3. Distribution of Ethnic Minorities

In order to clearly understand the distribution of each ethnic group, we used the obtained ethnic development index combined with ethnic toponym data. We used the 2018 NPP-VIIRS data as a base map, and used the point method to show the distribution of 25 ethnic minorities. Due to the large number of ethnic minorities, it was difficult to distinguish between ethnic groups using only different colors. This paper applied the literature [50] on the classification of language affiliation, and used the language branches of different ethnic minority languages to classify 25 ethnic minorities into 13 categories. Since the 13 categories were difficult to distinguish on the map, the 13 categories were merged into six categories based on the language branch classification. The specific classification is shown in Table 2.

Table 2. Language branch classification.

Branch	Ethnic Minority
Yi Branch	Yi, Lisu, Naxi, Bai, Lahu, Hani, Jinuo
Zhuang and Dai Branch	Zhuang, Buyi, Dai
Tibetan Branch	Tibetan
Jingpo Branch	Jingpo, Dulong
Chinese Branch	Hui, Manchu
Other Languages	Achang (Burmese branch), Shui (Dong Shui branch), Pumi; Nu; Mongolian, Deang (Undecided language), Miao (Miao branch), Yao (Yao branch), Wa; Bulang (Benglong language branch)

Since the development index of the Yi nationality was the highest, but less than 30, the 0–30 was divided into five categories by the equal interval: higher development index, high development index, medium development index, low development index,

and lower development index. According to the development index range of each type of development level, 25 ethnic minority development indexes were classified.

3. Results and Accuracy Verification

3.1. Ethnic Minority Development Index

In order to better reflect the development index of ethnic minorities, this article selecteed the Yi, Wa, Zhuang, Naxi, Hani, and Dai, six ethnic minorities with higher development indexes, for cartographic analysis. By comparing the development index calculated by Equation (3), and reference [49], the natural fracture method can most appropriately group similar values and maximize the difference between each class, so we compared the three methods of using the natural breaks method, average classification method, and manual breaks method, and found that the method using natural breaks method worked the best. This article divided the development index into five categories. The first category indicates areas with extremely poor development of the ethnic minorities, which are directly regarded as areas without the distribution of ethnic minorities. The second category indicates areas with poor development of the ethnic minority. The third category indicates areas with a moderate development. The fourth category indicates areas where the ethnic minority has developed well. The fifth category indicates areas with excellent development of the ethnic minority. The results are shown in Figures 4–9.

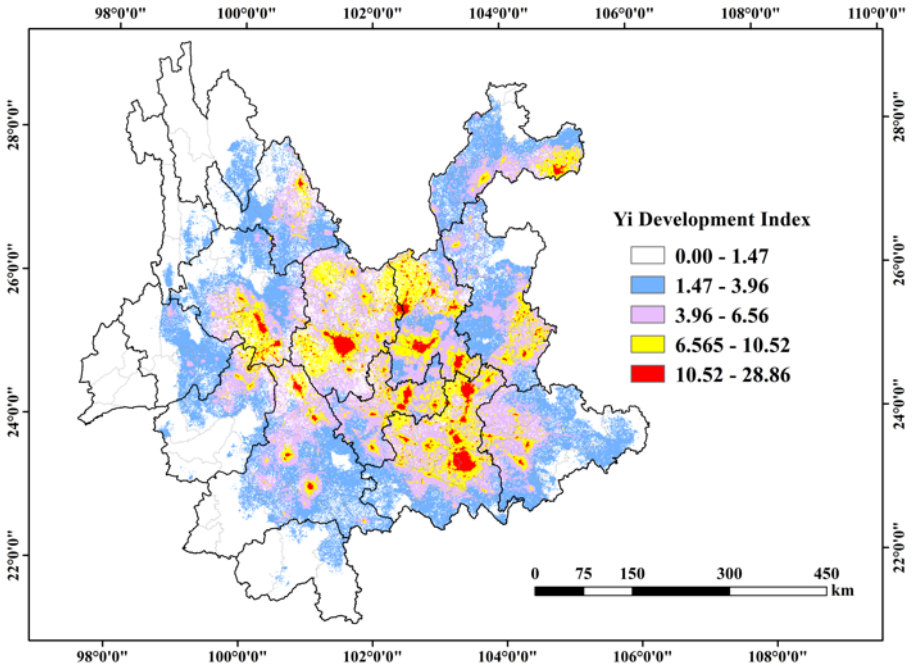

Figure 4. Yi nationality development index classification results.

It can be seen from Figures 4–9 that among the six ethnic minorities with high development indexes in Yunnan Province, the development indexes from high to low were: Yi, Wa, Zhuang, Naxi, Hani, and Dai. Moreover, the development index of Hani and Dai, Zhuang and Naxi were not much different. In other words, among the six ethnic minorities, the Yi ethnic group had the best development (the Yi ethnic group had the highest development index, and there were many areas with high development indexes), and the Dai ethnic group had the worst development compared to the other five ethnic minorities.

It can be seen from Figure 4 that the Yi nationality was distributed almost throughout Yunnan Province. The areas with higher Yi development index were: (1) the northeast area of Nanjian Yi County in Dali Bai Prefecture and the east area of Weishan Yi Hui County; (2) the eastern part of Chuxiong City, Chuxiong Yi Prefecture; (3) the junction of Wuhua District, Xishan District, Guandu District, and Panlong District of Kunming City,

the western part of Shilin Yi County, and the southern part of Luquan Yi and Miao County; (4) the southeast area of Eshan Yi County, Yuxi City, and the east area of Yuxi City; and (5) the northern area of Mile County, the western area of Kaiyuan City, the western area of Mengzi County, and the eastern area of Gejiu City in Honghe Hani and Yi Prefecture.

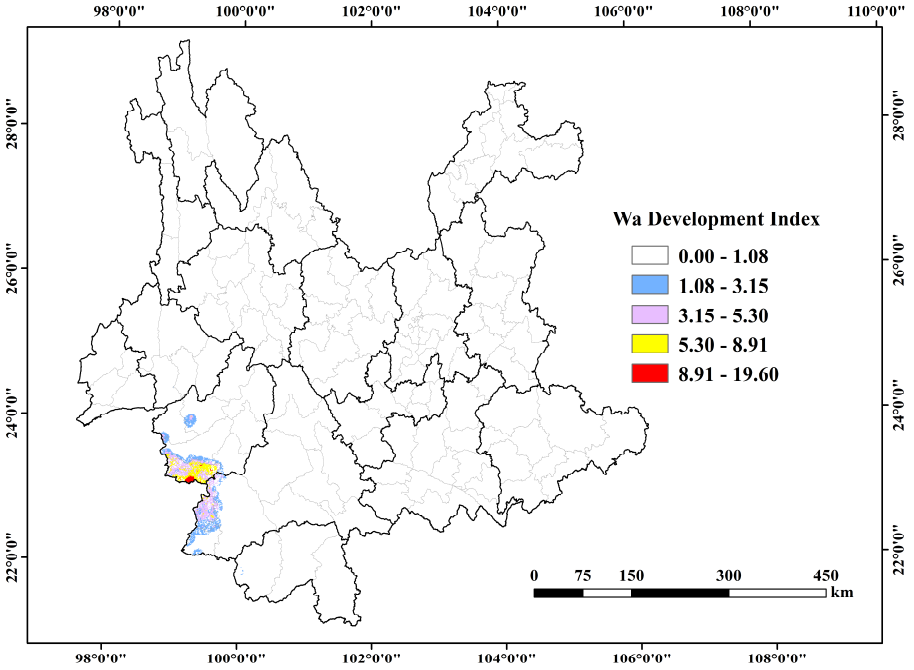

Figure 5. Wa nationality development index classification results.

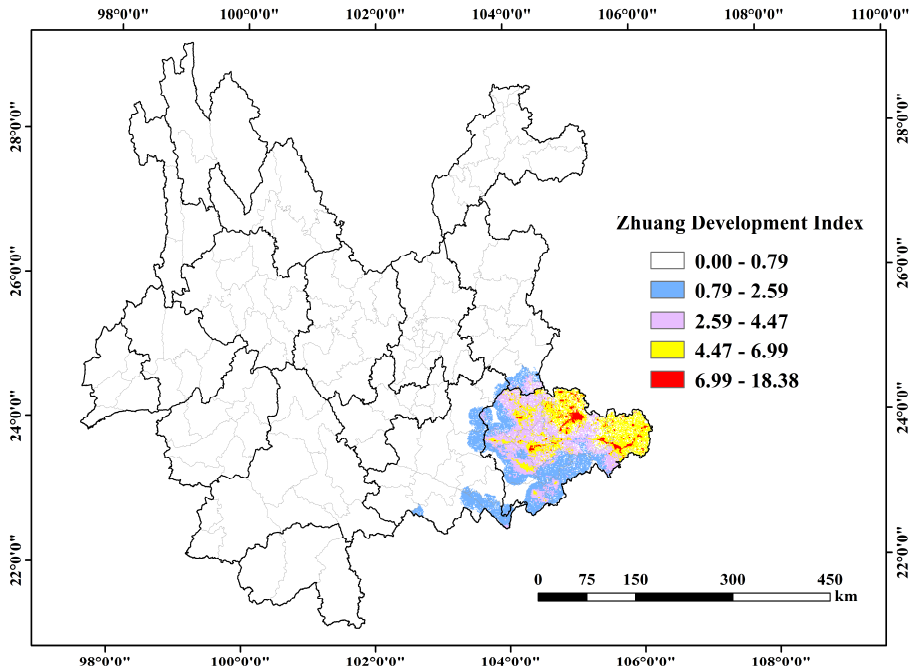

Figure 6. Zhuang nationality development index classification results.

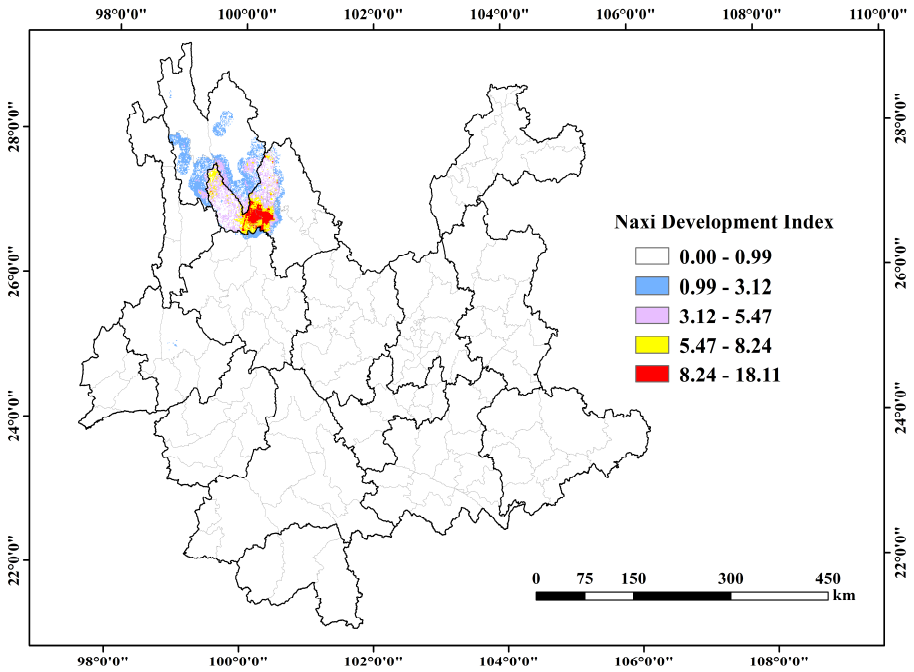

Figure 7. Naxi nationality development index classification results.

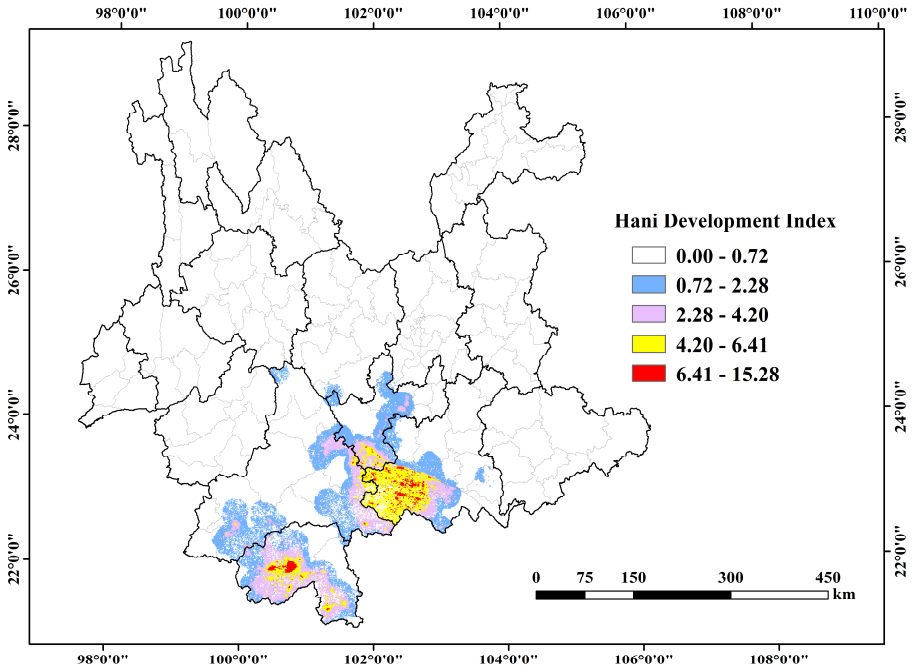

Figure 8. Hani nationality development index classification results.

It can be seen from Figure 5 that the distribution of the Wa nationality had regional characteristics, mainly in Cangyuan Wa County in Lincang City and Ximeng Wa County in Pu'er City. Between them, the Wa development index was the highest in the southern area of Cangyuan Wa County.

It can be seen from Figure 6 that the Zhuang nationality was mainly distributed in Wenshan Zhuang and Miao Prefecture. The areas with higher Zhuang development index were: (1) Qiubei County and the central area of Yanshan County; (2) the northern part of Funing County; and (3) the northwestern part of Guangnan County.

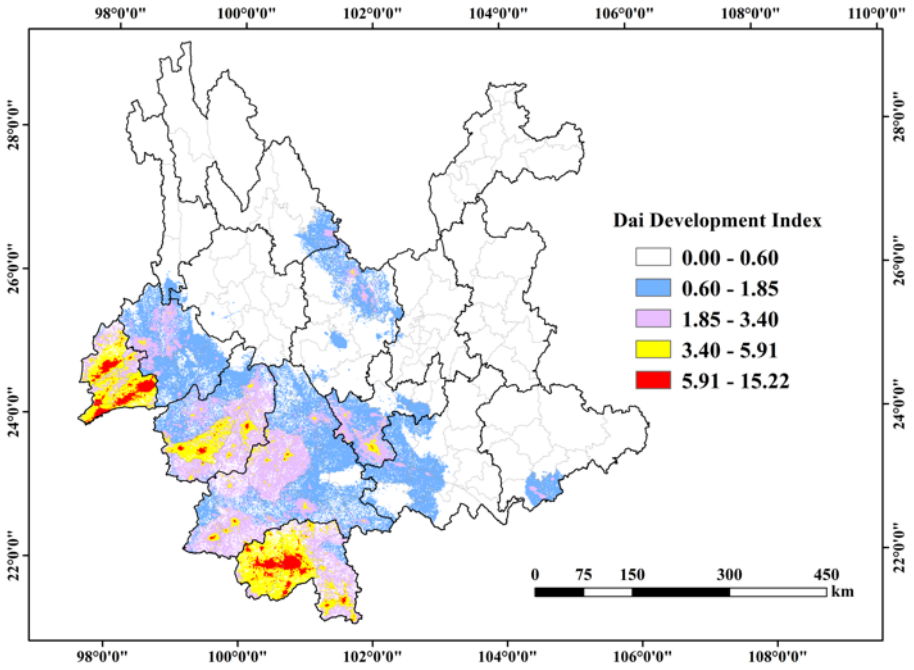

Figure 9. Dai nationality development index classification results.

It can be seen from Figure 7 that the Naxi nationality was mainly distributed in the western region of Lijiang City. The development index of the Naxi nationality was higher in the southern area of Lijiang urban and the southern area of Yulong Naxi County.

It can be seen from Figure 8 that the Hani nationality was mainly distributed in Xishuangbanna Dai Prefecture, southwest of Honghe Hani and Yi Prefecture, and southeast of Pu'er City. The areas with higher Hani development index were: (1) the western area of Jinghong City and the eastern area of Menghai County; (2) the central area of Hani and Yi County in Jiangyu; and (3) Honghe County, Yuanyang County, and Luchun County. It has the characteristics of not being concentrated and more scattered.

It can be seen from Figure 9 that the Dai nationality was mainly distributed in Dehong Dai Jingpo Prefecture, Lincang City, Xishuangbanna Dai Prefecture, Pu'er City, Baoshan City, and the western area of Yuxi City. The areas with higher Dai development index were: (1) Yingjiang County and Ruili City's southern area, and Mang City's central area; (2) the central area of Menghai County and Jinghong City; (3) Lincang city center and the central area of Gengma Dai and Wa County; (4) the central area of Yuanjiang County; and (5) the central areas of Menglian County, Lancang County, and Jinggu County.

3.2. Ethnic Minority Distribution Results

We used the method of in Section 2.2.3 to obtain the distribution results of 25 ethnic minorities in Yunnan Province (Figure 10).

It can be seen from Figure 10 that the coverage of the Yi ethnic group was the widest, involved the most counties, and was concentrated in Chuxiong Prefecture, the southeastern area of Qujing City, and the northern area of Kunming. The Jingpo branch is mainly distributed in Dehong Prefecture and Gongshan County. Zhuang Dai language branch was mainly distributed in Wenshan Prefecture, Dehong Prefecture, Xishuangbanna Prefecture, and Lincang Prefecture. The Chinese branch was mainly distributed in Zhaotong City and Baoshan City. Other language branches were mainly distributed in the east of Zhaotong and the north of Zhaotong, the east of Wenshan Prefecture, Nujiang Prefecture, Lijiang City, Dehong Prefecture, Xishuangbanna Prefecture, and the south of Lincang Prefecture.

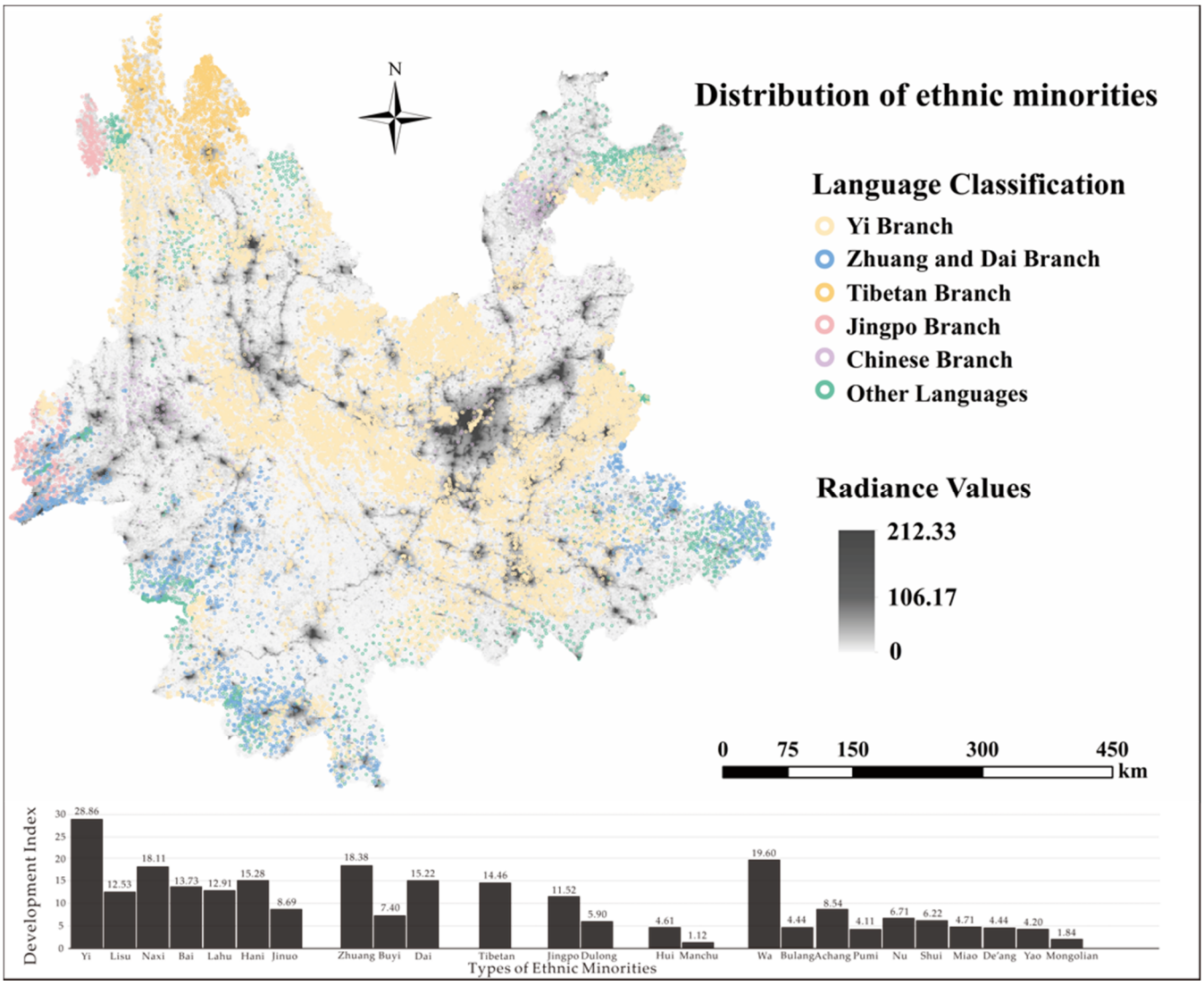

Figure 10. Distribution of ethnic minorities in Yunnan Province.

From the perspective of development index, the higher developed ethnic minority was the Yi. The high-developed index ethnic minorities included the Naxi, Zhuang, and Wa. The medium-developed ethnic minorities included the Hani, Bai, Lahu, Lisu, Dai, and Tibetan. The low-developed ethnic minorities included the Jingpo, Jinuo, Buyi, Achang, Nu, and Shui. The lower-developed ethnic minorities included Dulong, Bulang, Pumi, Miao, Hui, Manchu, De'ang, Yao, and Mongolian.

From the perspective of the language branch, the overall development index of ethnic minorities in the Yi, Zhuang, Dai, and Tibetan branch was relatively high, which may be related to the inheritance and development of these language branches.

Several ethnic minorities lived together in most areas. Among them, the mixed living of ethnic minorities in Dehong Prefecture was more obvious. Areas where the phenomenon of multi-ethnic mixed living was more obvious were: (1) Zhaotong City has mixed living of Yi branch, Chinese Branch, and other languages; (2) Funing County and Guangnan County in Wenshan Prefecture had mixed living of the Zhuang and Dai branch, and other languages; (3) Fumin County in Kunming City had mixed living of the Yi branch, Chinese Branch, and other languages; (4) Mengla County in Xishuangbanna Prefecture had mixed living of the Zhuang and Dai branches and other languages. (5) Jinghong City in Xishuangbanna Prefecture has mixed living of Zhuang and Dai branches and other languages, Yi branch, and Jingpo branch; (6) Longchuan County in Dehong Prefecture

had mixed living of Zhuang and Dai branches, other languages, and Jingpo branch; (7) Yingjiang County in Dehong Prefecture had mixed living of Zhuang and Dai branches, other languages, Yi branch, and Jingpo branch; and (8) Lushui County in Nujiang Prefecture had mixed living of other languages and the Yi branch.

There are currently 25 ethnic minorities in Yunnan Province, among which the Yi nationality is the most widely distributed and relatively scattered. Among the six selected ethnic minorities with the highest development index, from the perspective of each development index, the Yi nationality's development index was the highest, reaching 28.86 (to two decimal places). The Wa nationality had the second development index, reaching 19.60, but was far from the Yi nationality, which had the highest ranked development index. The Zhuang nationality had the third development index, reaching 18.38. The Naxi nationality had the fourth development index, reaching 18.11. The Hani nationality had the fifth development index, reaching 15.28. The Dai nationality's development index was the lowest at 15.22.

From the perspective of the relationship between the development index of each ethnic group and the geographic location of the ethnic group: the six areas with higher development indexes of ethnic minorities were located in the corresponding ethnic minority states, counties, or the city center of each city. Ethnic minorities had the highest development index in their corresponding minority prefecture or county, and the further the distance from the minority prefecture or county, the smaller the development index. The minority development index decreased as the distance between the minority nationality and its core development zone increased.

From the perspective of the relationship between each ethnic development index and the corresponding ethnic minority prefecture and county, areas with a higher ethnic development index were concentrated in the ethnic minority prefecture or county, but the development of the ethnic minority in the prefecture was better than that in the county.

3.3. Accuracy Verification

In order to verify the correctness of the development index calculated by the method used in this article, the method used in this article was compared with the method of the traditional research statistical yearbook. Considering that the development of a region is affected by many factors such as rural population, urban population, employment rate, average resident salary, etc., it is difficult to verify the correctness of the results of this article by selecting only one indicator. Comprehensively referenced in [51–53], this article selected eight indicators for the study area from 2013 to 2018. These were the total output value of agriculture, forestry, animal husbandry, and fishery in each county, and the per capita disposable income of rural residents in each county. County GDP per capita, GDP index of each county, rural employees in each county, rural population in each county, average salary of employees in each county, and number of employees in each county. Since the magnitudes of the eight indicators were different, the indicators were normalized first. The normalized formula is shown in Equation (4):

$$X = \frac{\mathrm{x} - \min}{\max - \min}, \tag{4}$$

where X is the standardized result of the index; x is the original value of the index; max is the maximum value of the sample data; and min is the minimum value of the sample data.

After obtaining the normalized results of the indicators, a comprehensive development index was established according to the method of establishing a comprehensive poverty index in the literature [53,54]. First, the entropy method was used to determine the weight of the eight indicators. In the entropy method, the larger the amount of information, the smaller the uncertainty of the information, and the smaller the entropy value, so the greater the weight. Using the entropy method to calculate the weight of each indicator, we

can obtain the comprehensive development index. The calculation formula is shown in Equations (5)–(8):

$$Z = \sum_{i=1}^{n} w_j * X_i, \tag{5}$$

$$f_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}, \tag{6}$$

$$H_j = -(1/\ln m)\sum_{i=1}^{m} f_{ij} \ln f_{ij}, \tag{7}$$

$$w_j = \frac{(1 - H_j)}{\sum_{j=1}^{n} (1 - H_j)}, \tag{8}$$

where f_{ij} is the index value weight of the i evaluation object under the j index; m is the 129 counties included in the study area; n is the eight indicators to construct the comprehensive development index; Z is the comprehensive development index; X_i is the standardized result of i evaluation object; H_j is the entropy value of the j index; and w_j is the weight of the j index.

The weights of the eight indicators in 2013–2018 calculated by the formula are shown in Table 3 (with four decimal places).

Table 3. The calculation results of the weight of each indicator from 2013 to 2018.

Indicators \ Year	2013	2014	2015	2016	2017	2018
GDP per capita	0.1446	0.1401	0.1350	0.1304	0.1321	0.1330
GDP Index	0.0419	0.0152	0.0252	0.0183	0.0144	0.0277
Number of employees	0.3597	0.3630	0.3752	0.3732	0.3755	0.3716
Average salary of employees	0.0057	0.0059	0.0052	0.0086	0.0090	0.0093
Per capita disposable income of rural residents	0.0171	0.0239	0.0232	0.0230	0.0225	0.0222
Total output value of agriculture, forestry, animal husbandry and fishery	0.1569	0.1503	0.1456	0.1453	0.1444	0.1438
Rural population	0.1636	0.1646	0.1649	0.1667	0.1641	0.1665
Rural workers	0.1520	0.1507	0.1507	0.1526	0.1523	0.1533

According to the calculation results of the weight of each index, the comprehensive development index of each county in the study area was obtained, as shown in Table 4.

Table 4. The results of the comprehensive development index of each county from 2013 to 2018.

County \ Year	2013	2014	2015	2016	2017	2018
Wuhua	0.5565	0.4184	0.4553	0.5595	0.5919	0.5626
Panlong	0.4935	0.5719	0.4175	0.5943	0.4999	0.5973
Guandu	0.4058	0.5501	0.5886	0.5818	0.5571	0.5577
Xishan	0.4362	0.5920	0.3979	0.3641	0.5711	0.3423
Dongchuan	0.2069	0.1855	0.1970	0.1763	0.1263	0.1595
Chenggong	0.1706	0.2412	0.3289	0.5510	0.5790	0.5906
Jinning	0.2200	0.1880	0.1278	0.1258	0.1740	0.1603
Fumin	0.0309	0.1454	0.1275	0.0793	0.0285	0.1881
Yiliang	0.0802	0.1650	0.1813	0.2292	0.2224	0.2432
Shilin	0.1635	0.3860	0.0723	0.1983	0.1256	0.1756
Songming	0.2307	0.1250	0.1700	0.1531	0.2550	0.2424
Luquan	0.1190	0.0354	0.0404	0.2198	0.0635	0.0625
Xundian	0.0482	0.0228	0.1243	0.1005	0.0759	0.0975
Anning	0.1812	0.0925	0.1538	0.2232	0.2606	0.2492

Table 4. *Cont.*

County \ Year	2013	2014	2015	2016	2017	2018
Qilin	0.2941	0.2193	0.2126	0.3072	0.2386	0.2395
Malong	0.1123	0.1928	0.1693	0.0839	0.1293	0.2136
Luliang	0.1289	0.1170	0.0310	0.0507	0.1856	0.0680
Shizong	0.0929	0.0283	0.1104	0.0220	0.0602	0.1154
Luoping	0.0533	0.0200	0.1049	0.1091	0.1217	0.1467
Fuyuan	0.1455	0.1421	0.1275	0.1070	0.1327	0.1951
Huize	0.1337	0.1262	0.0275	0.0728	0.0610	0.0458
Zhanyi	0.1868	0.1564	0.1065	0.0506	0.0582	0.1565
Xuanwei	0.1228	0.1014	0.1931	0.0926	0.1288	0.1064
Hongta	0.3898	0.2574	0.2017	0.2177	0.3029	0.2844
Jiangchuan	0.2124	0.2147	0.1954	0.1948	0.2097	0.2263
Chengjiang	0.2890	0.2553	0.2037	0.1633	0.2272	0.2198
Tonghai	0.1425	0.0818	0.1842	0.2408	0.2071	0.2459
Huaning	0.0806	0.0789	0.1427	0.0529	0.1255	0.1587
Yimen	0.0270	0.1556	0.1092	0.0388	0.0239	0.1186
Eshan	0.1073	0.1150	0.0641	0.1003	0.0377	0.1089
Xinping	0.0507	0.1436	0.0201	0.0203	0.1204	0.1154
Yuanjiang	0.0563	0.0205	0.0623	0.0751	0.0713	0.1310
Longyang	0.0422	0.0615	0.1098	0.0220	0.0541	0.0646
Shidian	0.0196	0.0898	0.0342	0.0203	0.0542	0.1068
Tengchong	0.0290	0.0575	0.0766	0.0439	0.0550	0.1588
Longling	0.1197	0.0751	0.0888	0.0423	0.0244	0.0209
Changning	0.0450	0.0403	0.0283	0.0782	0.0783	0.1131
Zhaoyang	0.1454	0.0551	0.1440	0.1380	0.1399	0.1832
Ludian	0.0938	0.1802	0.1376	0.1312	0.1831	0.2062
Qiaojia	0.1017	0.0723	0.0385	0.0712	0.0211	0.1004
Yanjin	0.0391	0.0204	0.0759	0.0422	0.1075	0.1131
Daguan	0.1040	0.0895	0.0613	0.1594	0.1380	0.1172
Yongshan	0.1071	0.1135	0.0575	0.1412	0.0964	0.0843
Suijiang	0.1458	0.0706	0.0896	0.0864	0.0877	0.0756
Zhenxiong	0.0600	0.0408	0.0878	0.0424	0.0297	0.0558
Yiliang	0.1195	0.1198	0.1100	0.0821	0.0885	0.1049
Weixin	0.0859	0.0209	0.0809	0.1667	0.1223	0.0757
Shuifu	0.0223	0.0302	0.0634	0.0380	0.0706	0.1554
Gucheng	0.0924	0.0613	0.0887	0.0946	0.1542	0.1332
Yulong	0.0197	0.0201	0.0578	0.0211	0.0302	0.0342
Yongsheng	0.0447	0.0215	0.0626	0.0393	0.0251	0.0568
Huaping	0.0271	0.0917	0.0322	0.0201	0.0556	0.0243
Ninglang	0.0247	0.0216	0.0632	0.0393	0.1433	0.0790
Simao	0.0651	0.0913	0.0317	0.0801	0.0302	0.0564
Ning'er	0.0214	0.0308	0.0895	0.0216	0.0480	0.1134
Mojiang	0.0253	0.0327	0.0297	0.0344	0.0605	0.0199
Jingdong	0.0474	0.1037	0.0204	0.1062	0.1195	0.0205
Jinggu	0.1055	0.1084	0.0374	0.0449	0.0464	0.0528
Zhenyuan	0.0360	0.0397	0.0409	0.0687	0.0601	0.0623
Jiangcheng	0.0264	0.0302	0.0202	0.0435	0.1008	0.0237
Menglian	0.0294	0.0202	0.0457	0.0207	0.0453	0.0267
Lancang	0.0671	0.0458	0.0204	0.0510	0.0640	0.1807
Ximeng	0.0813	0.0196	0.0208	0.0767	0.0207	0.2507
Linxiang	0.0295	0.0204	0.1297	0.0450	0.0535	0.0206
Fengqing	0.0199	0.1145	0.0513	0.0888	0.0207	0.1274
Yunxian	0.0334	0.0656	0.0211	0.0209	0.0321	0.0962
Yongde	0.0273	0.0264	0.0206	0.0403	0.1061	0.1245
Zhenkang	0.1196	0.0242	0.1059	0.0640	0.0198	0.0520
Shuangjiang	0.0833	0.0486	0.0206	0.0440	0.0528	0.0883
Gengma	0.0389	0.0459	0.0480	0.0325	0.0205	0.0563
Cangyuan	0.0317	0.0201	0.0312	0.0276	0.0352	0.0569
Chuxiong	0.0251	0.0231	0.1089	0.0338	0.2816	0.1152

Table 4. *Cont.*

County \ Year	2013	2014	2015	2016	2017	2018
Shuangbo	0.0299	0.0536	0.0210	0.1057	0.0997	0.0580
Mouding	0.1196	0.0204	0.1000	0.1567	0.2166	0.1957
Nanhua	0.0581	0.0204	0.1086	0.0968	0.1148	0.1205
Yao'an	0.0496	0.0685	0.0392	0.0620	0.0336	0.0608
Dayao	0.0471	0.0208	0.0578	0.0443	0.0625	0.0219
Yongren	0.0384	0.0339	0.0499	0.0897	0.0200	0.0800
Yuanmou	0.0200	0.0208	0.0824	0.0914	0.0456	0.0410
Wuding	0.0621	0.0281	0.0825	0.0366	0.0553	0.2346
Lufeng	0.0287	0.0322	0.0937	0.0561	0.1170	0.1709
Mengzi	0.0761	0.0203	0.0214	0.0760	0.1079	0.0890
Gejiu	0.0284	0.1278	0.1015	0.0870	0.1264	0.1201
Kaiyuan	0.0455	0.1137	0.1624	0.1265	0.1662	0.1792
Mile	0.0906	0.1955	0.1257	0.1705	0.1895	0.1721
Pingbian	0.0353	0.0507	0.0206	0.0807	0.1048	0.0269
Jianshui	0.0201	0.0705	0.0245	0.0418	0.1063	0.0564
Shiping	0.0199	0.0380	0.1395	0.0611	0.1143	0.0946
Luxi	0.1447	0.0652	0.0994	0.0891	0.0717	0.0992
Yuanyang	0.0199	0.0638	0.0708	0.0309	0.0922	0.0706
Honghe	0.0230	0.1195	0.0217	0.0256	0.0238	0.1657
Jinping	0.0509	0.0202	0.0208	0.0207	0.0317	0.0206
Luchun	0.0477	0.0621	0.0290	0.0359	0.0618	0.0369
Hekou	0.0678	0.0488	0.0540	0.0390	0.0466	0.0206
Wenshan	0.1196	0.0734	0.0784	0.0527	0.1758	0.1454
Yanshan	0.0590	0.0655	0.0204	0.0804	0.0204	0.1157
Xichou	0.1082	0.0495	0.0737	0.0613	0.0949	0.1313
Malipo	0.1195	0.1039	0.0898	0.0211	0.1296	0.2052
Maguan	0.0538	0.0537	0.0206	0.0208	0.0878	0.1211
Qiubei	0.0212	0.0522	0.0347	0.0264	0.0746	0.0210
Guangnan	0.1195	0.0275	0.0352	0.0208	0.0579	0.0204
Funing	0.0200	0.0202	0.0390	0.0370	0.0244	0.0225
Jinghong	0.0339	0.0985	0.1048	0.1219	0.1242	0.0996
Menghai	0.0286	0.0216	0.0309	0.0324	0.0738	0.0533
Mengla	0.0546	0.1012	0.1310	0.1316	0.0516	0.1163
Dali	0.2015	0.1204	0.2399	0.2192	0.1301	0.1922
Yangbi	0.0202	0.0489	0.0407	0.0577	0.1129	0.0841
Xiangyun	0.0971	0.0307	0.0752	0.0860	0.1438	0.1869
Binchuan	0.0358	0.1710	0.0278	0.0977	0.1210	0.0878
Midu	0.0577	0.1017	0.0822	0.1511	0.0946	0.1239
Nanjian	0.0218	0.0967	0.0246	0.0510	0.1526	0.0868
Weishan	0.0534	0.1220	0.0705	0.1026	0.0599	0.0919
Yongping	0.0740	0.0848	0.0351	0.0952	0.0422	0.0622
Yunlong	0.0422	0.1352	0.0734	0.1527	0.1387	0.2176
Eryuan	0.0214	0.0419	0.0310	0.0206	0.0202	0.1260
Jianchuan	0.0379	0.0366	0.0211	0.0832	0.1196	0.0851
Heqing	0.0715	0.0213	0.0658	0.0636	0.0688	0.0851
Mangshi	0.0200	0.1012	0.1463	0.1428	0.1542	0.0607
Ruili	0.0626	0.1126	0.0557	0.0518	0.1487	0.2090
Lianghe	0.0343	0.1255	0.0221	0.0202	0.1423	0.1570
Yingjiang	0.1195	0.0694	0.1095	0.0374	0.2701	0.0613
Longchuan	0.0256	0.0949	0.0204	0.0198	0.0495	0.1184
Lushui	0.0209	0.0219	0.0874	0.1034	0.0254	0.0943
Fugong	0.0289	0.0288	0.0217	0.0427	0.0465	0.0644
Gongshan	0.0204	0.0498	0.0332	0.1214	0.0707	0.0924
Lanping	0.0272	0.0383	0.0282	0.0199	0.0686	0.0912
Shangri-La	0.3128	0.4385	0.2572	0.4639	0.4023	0.4179
Deqin	0.0506	0.0309	0.0282	0.0950	0.0798	0.0859
Weixi	0.0772	0.0261	0.0730	0.1198	0.0490	0.0460

Using the method developed in this article to calculate the comprehensive development index of all ethnic minorities and Han nationality in the study area from 2013 to 2018, we performed district statistics on the development index of each county on ArcMap, and took the average value of the development index of each county as the statistical value. The development index of each county from 2013 to 2018 is shown in Table 5.

Table 5. The development index result calculated by the method in this paper.

County \ Year	2013	2014	2015	2016	2017	2018
Wuhua	2333.1825	2339.1373	2376.7834	2394.4854	2415.8620	2448.1288
Panlong	2470.0052	2554.7521	2333.1047	2404.9305	2504.0174	2511.2501
Guandu	2170.9487	2259.7741	2353.8594	2381.0156	2449.4958	2561.8397
Xishan	1621.7904	1784.9426	1598.3018	1565.5310	1597.4138	1602.9692
Dongchuan	960.6572	994.8467	742.9193	836.3549	854.5164	934.8275
Chenggong	943.5753	1076.5617	1205.3264	2298.8631	2363.8025	2420.8939
Jinning	595.8789	627.4076	688.4572	711.8920	830.7505	850.9899
Fumin	612.8931	695.4732	746.5198	784.6463	789.6833	897.2893
Yiliang	625.2049	761.7744	830.1322	886.5681	962.0898	996.5625
Shilin	766.8347	789.6061	794.6279	825.1524	891.7881	985.6760
Songming	899.6777	927.3485	946.6784	973.7795	1107.7790	1056.7363
Luquan	320.2183	364.9809	400.2450	438.9507	448.5508	576.7864
Xundian	517.4374	522.8907	539.6836	574.8628	601.3995	746.0349
Anning	945.3103	955.8508	957.5187	1008.2649	1050.5527	1084.9657
Qilin	1069.2507	1084.1809	1090.9449	1116.4519	1172.8232	1240.0189
Malong	649.2351	693.1274	712.2659	729.2838	757.7143	860.7674
Luliang	543.4304	554.4877	576.5027	589.5539	595.1228	638.4553
Shizong	483.0773	485.1854	500.8513	519.5551	526.3722	657.7111
Luoping	491.1515	417.1506	518.5569	531.6147	554.2872	672.6678
Fuyuan	633.7029	641.5798	652.7819	663.3065	674.2953	782.7485
Huize	617.1130	647.3857	481.3886	507.0445	558.0216	605.9378
Zhanyi	600.3138	635.8879	660.7369	673.4620	696.3811	843.4202
Xuanwei	623.7029	656.5798	662.7819	673.3065	684.2953	796.7485
Hongta	1276.6486	1310.7777	1255.3083	1207.8354	1358.3035	1377.4974
Jiangchuan	897.7480	912.4791	947.5681	952.9043	1104.6690	1133.9384
Chengjiang	1004.5388	1031.805437	1047.223082	1074.157544	1149.89266	1157.818511
Tonghai	883.0552	919.5813	957.5814	990.6898	1062.5763	1117.2477
Huaning	585.7714	595.2825	640.7928	658.2505	715.3348	811.3422
Yimen	494.4001	511.3989	532.8776	551.4176	555.8165	693.6572
Eshan	489.2267	549.9414	580.4157	593.6294	615.8568	664.5724
Xinping	260.6868	421.3788	415.0625	415.7112	453.7176	537.3233
Yuanjiang	486.8459	539.9640	559.4845	596.8433	624.0441	689.0722
Longyang	433.3167	507.6858	521.9453	535.2050	590.8690	664.5847
Shidian	297.5054	455.6399	417.2362	473.0716	502.3391	582.7547
Tengchong	381.8499	569.4589	552.5687	604.0656	669.7669	753.0422
Longling	283.7437	472.8197	460.4084	499.1058	498.2598	612.5852
Changning	299.6858	441.3997	467.5553	447.8070	469.2807	565.8577
Zhaoyang	803.7647	813.1024	880.7033	856.9120	885.1878	954.2087
Ludian	640.0504	697.3706	741.4808	756.5885	772.3398	868.5031
Qiaojia	461.1212	479.4775	498.7038	540.6888	592.3084	670.8998
Yanjin	427.3850	495.8935	540.4706	557.9826	565.5458	616.2725
Daguan	529.7191	622.5744	655.1364	689.8198	755.0185	767.3721
Yongshan	696.0273	684.1769	741.3797	744.1170	810.3069	884.5728
Suijiang	626.3479	600.9896	614.0467	641.6444	706.0032	718.7469
Zhenxiong	448.4068	454.1750	578.5055	497.7722	473.2344	564.0579
Yiliang	455.5056	426.6301	535.4907	578.2334	588.6284	642.6751
Weixin	649.2141	576.1327	623.3148	665.7798	808.1880	817.0238
Shuifu	477.7044	536.3990	554.4428	565.6362	624.9817	672.7901
Gucheng	715.5696	656.3005	791.5617	844.6705	659.9559	730.8966
Yulong	249.8526	278.7471	289.6164	322.6217	348.7171	434.7898
Yongsheng	306.8789	315.7225	339.0830	358.6972	367.6797	455.4456
Huaping	398.2136	435.1668	448.9292	465.1374	473.1283	529.3849

Table 5. *Cont.*

County \ Year	2013	2014	2015	2016	2017	2018
Ninglang	483.3725	499.1192	503.1318	532.7423	568.5116	556.7700
Simao	262.0737	378.4076	411.3063	423.9178	428.7674	515.5211
Ning'er	205.7700	345.3506	377.4181	363.9567	380.2126	492.3221
Mojiang	294.4344	320.0161	345.7805	360.6149	368.5020	492.5927
Jingdong	285.6620	323.7440	442.4544	445.8952	451.9286	557.7185
Jinggu	204.1723	204.5097	286.7719	300.7873	279.4673	347.8470
Zhenyuan	316.8741	345.1779	366.7534	369.0427	369.2104	463.5557
Jiangcheng	259.2867	353.5767	385.5516	390.8240	468.7765	490.3128
Menglian	214.4475	261.5678	354.3153	353.2323	388.4604	440.2223
Lancang	111.0612	131.2043	226.3668	288.6047	273.7476	333.1441
Ximeng	112.9200	172.0400	326.1849	337.2044	349.1749	407.7943
Linxiang	306.9635	462.6050	515.0650	507.7827	502.8663	588.0734
Fengqing	380.4210	587.8980	589.8904	608.2613	611.0447	714.5013
Yunxian	315.0365	499.6152	461.8195	532.8510	521.2354	619.7606
Yongde	226.1955	423.5674	434.0769	478.3543	459.3394	528.0003
Zhenkang	297.1114	355.5066	364.0461	370.0390	376.3777	433.9040
Shuangjiang	227.5567	287.2707	326.3009	387.4047	401.0221	468.4001
Gengma	217.7960	347.9124	396.2941	372.3042	356.5077	406.0964
Cangyuan	160.4840	309.5874	338.4399	339.9750	354.0869	416.7235
Chuxiong	433.2826	645.2557	653.4692	657.8736	681.1811	837.8980
Shuangbo	252.8526	303.8850	379.6348	390.3115	407.8300	520.8493
Mouding	310.4608	560.9061	615.7034	638.1917	696.1406	832.3970
Nanhua	480.4072	505.4462	609.2866	625.6880	638.3771	782.9123
Yao'an	209.0912	390.8838	467.7279	486.7033	523.6015	651.2314
Dayao	252.5988	349.5919	369.2466	413.5369	424.8047	538.7005
Yongren	345.9574	362.8734	373.2791	374.4745	446.5159	482.9805
Yuanmou	339.6947	476.3847	520.1060	529.2911	571.1880	670.1142
Wuding	247.2879	375.7019	384.2886	436.3690	459.5321	573.1000
Lufeng	478.5784	580.9119	586.9430	591.4193	655.7322	748.1127
Mengzi	457.9591	464.1473	470.5014	506.2215	511.0077	613.6647
Gejiu	572.3553	600.1590	591.4074	642.3799	690.1944	748.6155
Kaiyuan	668.0048	673.1953	604.3685	624.1396	766.4539	826.0011
Mile	671.0291	722.1276	726.0442	747.2656	792.8220	868.9230
Pingbian	305.4681	375.1979	417.6111	443.0900	444.3564	572.0882
Jianshui	399.9278	458.7829	479.0721	504.5566	511.8208	618.5614
Shiping	321.6694	424.4328	438.0587	446.9695	470.7730	563.0486
Luxi	592.6135	609.4124	631.0997	645.3875	709.2802	801.2388
Yuanyang	333.5136	363.3037	451.0659	478.7271	523.0667	617.0672
Honghe	258.5071	372.6793	447.6026	464.3542	490.1732	609.1840
Jinping	204.2935	221.5390	339.2894	356.5964	360.8186	465.1307
Luchun	91.9753	243.7047	264.9559	309.4107	322.8647	434.3615
Hekou	272.5834	350.7499	384.7263	391.4023	396.9577	475.4815
Wenshan	474.0788	490.4182	499.7623	533.9054	594.8506	672.3611
Yanshan	421.5922	437.0946	445.0354	464.4252	494.4376	596.4948
Xichou	508.0878	515.4572	575.0413	617.1873	628.6801	727.9660
Malipo	266.5631	402.8942	460.5780	461.5752	485.8210	588.7415
Maguan	293.9284	356.8797	399.5391	404.3396	448.7799	523.6682
Qiubei	331.6157	347.3116	384.0514	401.5665	404.9738	504.4938
Guangnan	266.2608	293.2710	311.7878	352.7943	359.1112	454.3619
Funing	240.5025	324.5929	340.5920	348.3029	363.3480	485.1750
Jinghong	399.9671	410.0248	452.5865	539.5053	556.8493	620.9858
Menghai	229.7981	276.6386	298.5195	306.0052	308.7728	339.3909
Mengla	562.3500	597.2580	617.6430	697.8365	700.8417	782.5778
Dali	894.2742	929.0856	952.3336	972.2778	1017.5021	1054.9061
Yangbi	409.4086	504.7738	535.1718	541.4113	592.4125	669.4222
Xiangyun	521.8522	635.7725	637.0776	639.2351	659.8403	773.7537
Binchuan	477.8487	515.6735	532.8143	547.7162	554.5976	662.9385
Midu	515.8058	614.6749	661.6881	669.8814	676.4856	796.9106

Table 5. *Cont.*

County \ Year	2013	2014	2015	2016	2017	2018
Nanjian	410.8299	532.0153	545.4751	554.5118	581.0947	724.9630
Weishan	495.9411	521.2475	521.6193	521.8876	559.1663	680.8504
Yongping	440.5821	478.1848	494.3199	528.8982	518.7397	631.0074
Yunlong	598.6572	619.4169	655.4769	698.7190	716.7159	765.8410
Eryuan	365.9509	434.7853	446.9512	463.0531	471.9941	590.1621
Jianchuan	312.4686	377.2469	403.1285	427.2047	436.7856	538.2106
Heqing	398.3198	406.8919	437.4106	440.9969	508.3256	571.2813
Mangshi	568.9163	643.5718	655.0890	658.2708	709.8286	727.3277
Ruili	585.2299	621.4004	640.0733	722.0235	729.4622	804.0055
Lianghe	343.3566	495.8395	512.3878	525.5199	542.1922	656.7071
Yingjiang	361.4221	362.8221	365.1339	366.4192	386.2395	472.1552
Longchuan	396.3737	424.4385	447.7375	450.1162	503.5420	574.8163
Lushui	338.0632	425.1091	511.3545	528.6956	621.6195	678.0960
Fugong	281.9702	301.0313	317.7124	378.3484	428.1135	499.3321
Gongshan	449.5138	542.8045	564.2108	653.6538	657.6125	728.4643
Lanping	379.1665	394.9759	399.0575	403.1246	427.0084	492.5050
Shangri-La	1421.7904	1484.9426	1498.3018	1568.5310	1588.4138	1616.9692
Deqin	491.5996	556.1296	606.6776	630.9152	639.8685	696.2319
Weixi	378.2066	389.1270	389.1924	403.1409	415.1711	494.6600

Then, we performed linear regression analysis on the comprehensive development index calculated by the traditional method and the development index calculated by the method in this paper to obtain the regression analysis result, as shown in Equation (9) and Figure 11.

$$y = 3294.3x + 275.43 \quad (9)$$

where x is the development index calculated by the traditional method; y is the development index calculated by the method in this paper; and R^2 is the correlation coefficient of the regression.

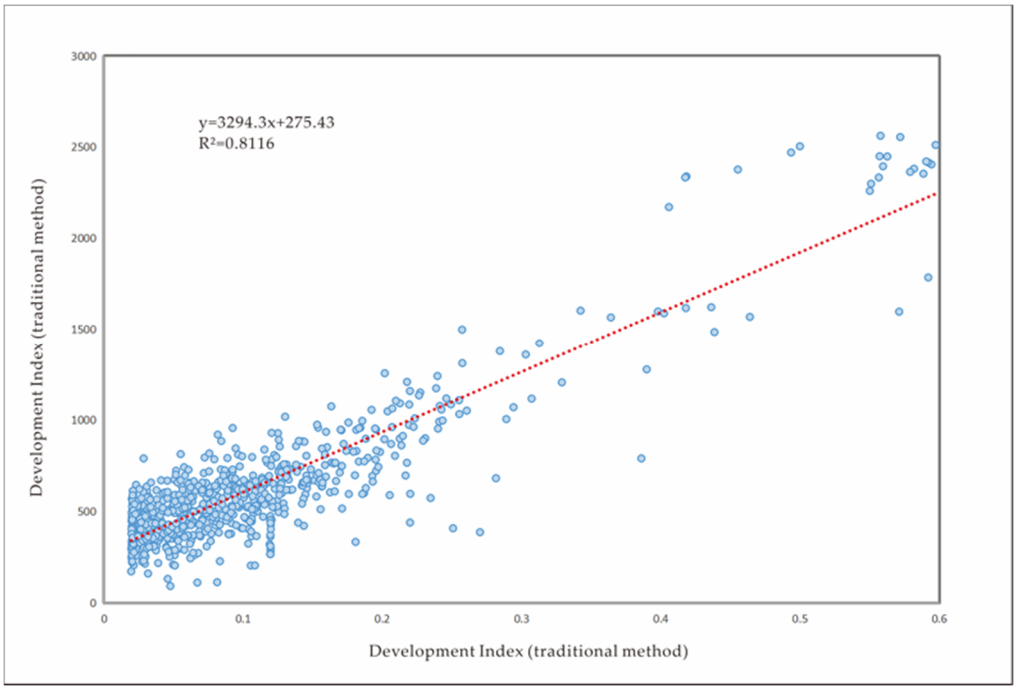

Figure 11. Linear regression results.

It can be seen from Figure 11 that the regression coefficient R^2 of the development index calculated using the method of this article and the development index calculated using the traditional method was 0.8116. When R^2 is greater than 0.8, it can be considered that the two variables are highly correlated. Therefore, the correctness of the method in this paper was proven.

4. Discussion

4.1. Significance to the Development of Ethnic Minorities

There are obvious differences in the development of different ethnic minorities and the development of the same ethnic minorities in different regions. This paper used the relationship between night-time light remote sensing data, economy, and population to establish the development index of ethnic minorities. The results can be analyzed by (1) the size of development differences among different ethnic minorities; (2) differences of the same minority in different minority prefectures and counties; and (3) the relationship between the development index of various ethnic minorities and geographical location. The factors in the ethnic development index model constructed in this paper can be changed, and more factors can be added according to different research purposes. This lays the foundation for the future development direction of ethnic minorities and the formulation of development policies.

Compared with the traditional research on statistical yearbooks, the method in this paper was faster, saved time, and could obtain the long-term national development status in time. In this way, we can quickly understand the development of each nation in time and space. For a multi-ethnic country, timely access to the development status of each ethnic group is conducive to adjusting policies on ethnic population, economic, and other fields to achieve coordinated and balanced development of all ethnic groups to the greatest extent, thereby reducing ethnic conflicts. The method studied in this article can not only target different ethnic groups, but can also be extended to different races and special groups (for example, using the method of this article to study the development of Blacks and Whites, and make a spatial distribution map), or different species. This is of great significance for the sustainable development and coordinated development of the world.

We used the method described in this article to calculate the development index of all ethnic groups in Yunnan Province, and used the natural discontinuity method to divide the development index into five categories. The first category was excellent-developed areas, the second category was well-developed areas, the third category was medium-developed areas, the fourth category was poor-developed areas, and the fifth category was very poor-developed areas. The classification results are shown in Figure 12.

4.2. The Relationship between National Development and Government

It can be roughly seen from the figure that the areas with higher national development index were mainly concentrated in the center of the county. We then counted the average distance from each type of grid to the nearest government by county. The average distance from each type of grid to the nearest government is shown in Table 6.

Table 6. The relationship between the level of national development and its average distance to the nearest government.

National Development Level	Average Distance to the Nearest Government (Unit: m)
Excellent-Developed	3352.28
Well-Developed	4695.77
Medium-Developed	6043.98
Poor-Developed	8728.84
Very Poor-Developed	12,411.90

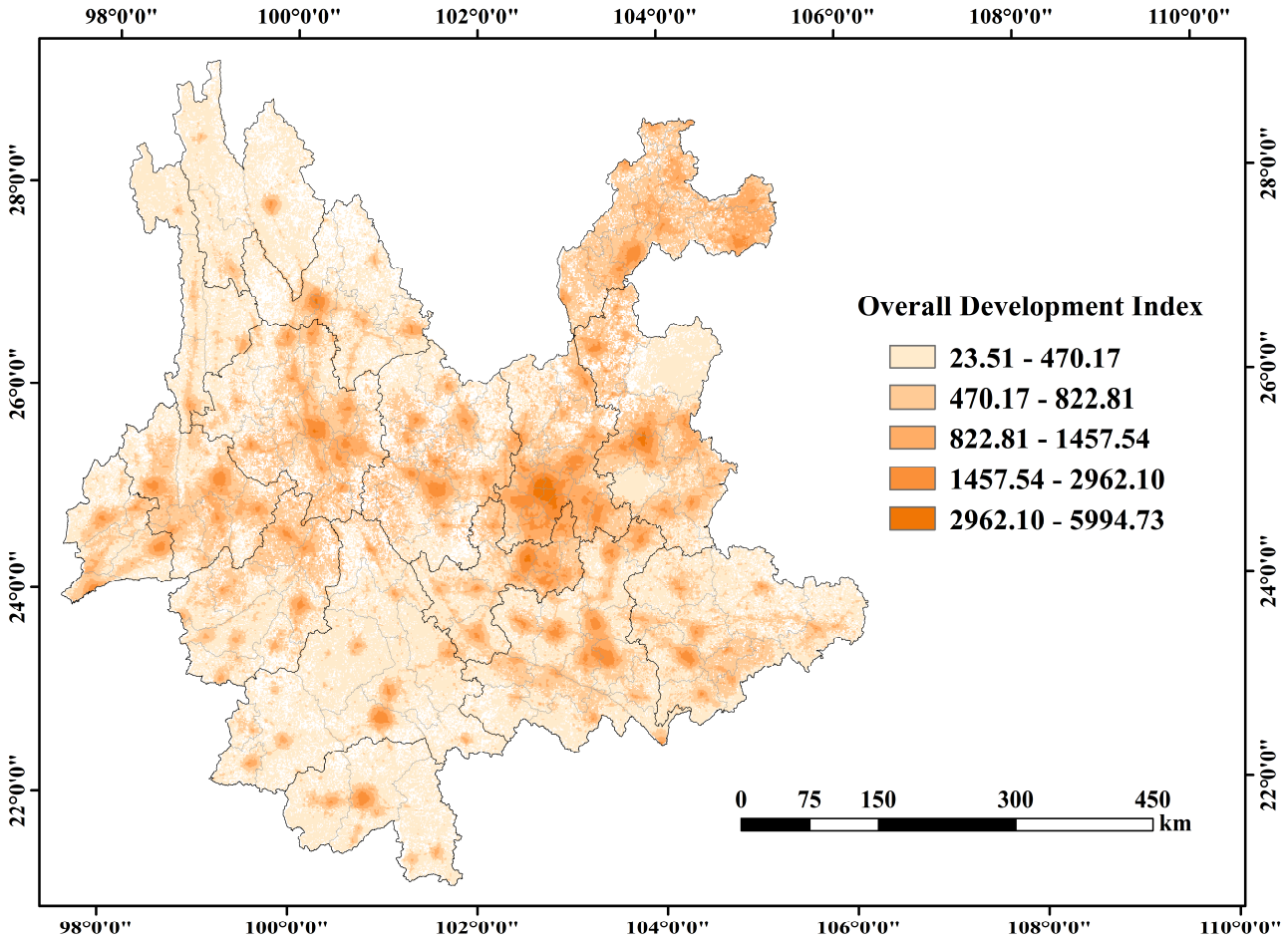

Figure 12. Yunnan Province nationality overall development index.

It can be seen from Table 6 that the area with excellent ethnic development is the closest to the local government. The farther the ethnic development zone is from the local government, the smaller the development index. The area with excellent ethnic development is about 3 km away from the local government, because in China, the development circle of a region is basically centered on the government and spreads around that. With the government as the center and a radius of 3 km, the higher the level of national development. With the continuous increase in the radius, the lower the level of development. Therefore, the government's assistance has played a very important role in the development of the nation.

First, we carried out regional statistics on the development index of each county, selected the average development index of each county as the benchmark, and classified the overall development index according to the county level. A grid map of the development of each county was obtained. Then, we extracted the best-developed grid center in each county, and calculated the distance between the grid center and the nearest local government. Finally, the development of each county and the distance between the best-developed areas of each county and the local government are shown on a map in Figure 13.

Generally speaking, the better-developed areas were closer to the local government. However, there were two situations on the map. First, the development of the region is better, but far from the government. The reason for this phenomenon is that the development strength of these regions is relatively strong, and the role of the government is not the main one relative to the development of the region. Second, the development of the region is poor, but is closer to the government. This phenomenon occurs because the government has not maximized its leading role in the development process of the region. In future development, we should pay attention to government assistance.

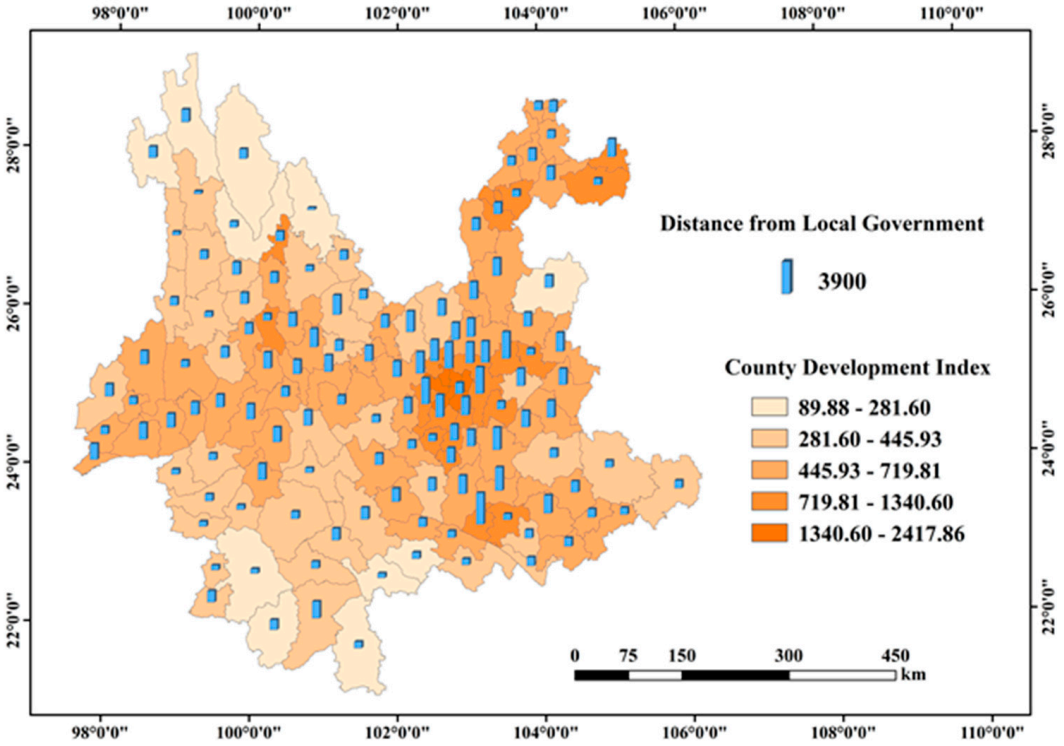

Figure 13. The development status of each county and the distance from the area with the highest development index of each county to the local government.

In the future development of nationalities, we must pay attention to giving play to the leading role of the government, mobilize the strength of all nationalities, and unite and assist each other in order to achieve better development.

4.3. Influence on Night-Time Light Remote Sensing Mapping

Night-time light remote sensing images have been widely used in economic monitoring, population mobility, environmental protection, and other fields, but there are relatively few studies [52] on night-time light remote sensing and the development of ethnic minorities. There is basically no literature on the study of ethnic minorities combined with night-time light data. This article fills this research gap to a certain extent. This paper combines toponym data, population data, and night-time light remote sensing data, considering the development of ethnic minorities from multiple perspectives. This mapping method provides a reference for subsequent similar studies. Special thematic mapping for ethnic minorities is also not common. The establishment of the ethnic minority development index plays a supporting role in dynamically monitoring the development of ethnic minorities and narrowing the development differences between ethnic minorities in various regions.

However, there are many development indexes that affect a region such as topography, population, and production patterns. Using the method in this article cannot reflect the importance of multiple variables, but can only be reflected by the brightness of night light illumination of night-time light data. The method in this article is more efficient for calculating the overall development index of a nation, but is not suitable to reflect the importance of each variable.

4.4. Significance of Cultural Protection of Ethnic Minorities

Due to industrialization and continuous economic development, people's production and lifestyles have undergone great changes, which has also caused many ethnic minority cultures to face crises. Therefore, we need to find the point of convergence between ethnic minority culture and economic development [55]. This article can understand the

development of ethnic minorities by establishing the minority development index, which is conducive to summarizing the development laws of ethnic minorities, and has a positive effect on the protection and inheritance of ethnic minority cultures. It also responds to the call of General Secretary Xi Jinping to pay attention to the protection and inheritance of ethnic minority cultural heritage.

5. Conclusions

This article used ethnic toponym data, population data, and NPP-VIIRS night-time light data to obtain the development index of each ethnic group, and analyzed the six ethnic minorities with high development index as examples. The results showed that among the six ethnic minorities, the Yi nationality had the highest development index (28.86), and the Dai had the lowest development index (15.22). After in-depth analysis, we found the relationship between the minority development index and the minority prefecture, county, and geographic location, that is, the minority development index decreased as the distance between the minority nationality and its core development prefecture and county increased. According to the obtained development indexes of ethnic minorities, combined with the toponym data of ethnic minorities, the 25 ethnic minorities were divided into 13 categories according to the language branch classification method. Each ethnic minority was classified according to the level of the development index, and a map of the distribution of ethnic minorities in Yunnan Province was obtained. The Yi were distributed in almost the entire study area, and the distribution of other ethnic minorities had obvious regional characteristics. The overall development index of ethnic minorities in the Yi, Zhuang. and Dai, and Tibetan branch was higher, and the overall development index of ethnic minorities in other language branches was lower. In most areas, multiple ethnic minorities lived together. Among them, this phenomenon was most obvious in Dehong Prefecture, which may be related to the geographical location and cultural precipitation of Dehong Prefecture. In Yunnan Province, the two ethnic minorities, Yi and Dai, live together more often with other ethnic minorities.

All in all, this paper constructed a method to calculate the development index of ethnic minorities based on NPP-VIIRS night-time light data. This method is faster and more intuitive than other qualitative analysis methods that have focused on research and statistical yearbooks. On one hand, this method makes up for the lack of corresponding economic data in rural areas and ethnic minority areas to a certain extent. On the other hand, this article provides a new idea to study the mapping of ethnic minorities and night-time light remote sensing data. This is of great significance to the development of ethnic minorities and the protection of ethnic minority culture.

Author Contributions: Conceptualization, F.Z.; Methodology, F.Z.; Validation, F.Z., L.S. and Z.P.; Formal analysis, L.S., Z.P., J.Y. and G.L.; Resources, Z.X.; Data curation, F.Z., L.S., J.Y. and Z.P.; Writing—original draft preparation, F.Z. and L.S.; Writing—review and editing, F.Z., Z.X., L.S., Z.P., J.Y., J.D., G.L., C.C., S.F. and Y.J.; Visualization, L.S.; Supervision, F.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (Grant No. 41961064); the Yunnan Department of Science and Technology application of basic research project (Grant No. 202001BB050030); Plateau Mountain Ecology and Earth's Environment Discipline Construction Project [Grant No.C1762101030017]; Joint Foundation Project between Yunnan Science and Technology Department and Yunnan University [Grants C176240210019]; Yunnan University Graduate Research and Innovation Fund Project (Grant No. 2020188).

Acknowledgments: The authors express their sincere gratitude to the Earth Observation Team, BigeMap Downloader, the National Geomatics Center of China, and the China Social Big Data Research Platform for providing the NPP-VIIRS images, POI data, toponym data, research area vector data, and census data.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ray, A.K. Measurement of social development: An international comparison. *Soc. Indic. Res.* **2008**, *86*. [CrossRef]
2. Fan, Q.; Lv, J.D.; Li, M. Prediction of GDP in Northeast China Based on Nighttime Light Data. *Remote Sens. Environ.* **2019**, *34*, 3–10.
3. Shi, K.F.; Yu, B.L.; Huang, Y.X.; Hu, Y.J.; Yin, B.; Chen, Z.Q.; Chen, L.J.; Wu, J.P. Evaluating the Ability of NPP-VIIRS Nighttime Light Data to Estimate the Gross Domestic Product and the Electric Power Consumption of China at Multiple Scales: A Comparison with DMSP-OLS Data. *Remote Sens.* **2014**, *6*, 1705–1724. [CrossRef]
4. Wang, J.N.; Lu, Y.T.; Zhou, J.S.; Li, Y.; Cao, D. Analysis of China resource-environment Gini coefficient based on GDP. *China Environ. Sci.* **2006**, *26*, 111–115.
5. Liang, Y.J.; Xu, Z.M. Modeling the Spatial Distribution of Population Based on Night Light Radiation and LUCC: A Case Study in Ganzhou District, Zhangye Municipality. *J. Glaciol. Geocryol.* **2012**, *34*, 999–1006.
6. Doll, C.N.; Pachauri, S. Estimating rural populations without access to electricity in developing countries through night-time light satellite imagery. *Energy Policy* **2010**, *38*, 5661–5670. [CrossRef]
7. Wang, Z.; Chen, J.H.; Cui, M.J. Prediction of GDP in Northeast China Based on Nighttime Light Data. *Mine Surv.* **2018**, *46*, 27–33.
8. Li, X.H.; Chen, J.Z. Study on the Economic Development Model of Ethnic Minorities from the Perspective of International Comparison Reg. *Reg. Econ. Rev.* **2020**, *3*, 18–24. [CrossRef]
9. Lu, M. A Study on the Status Quo and Countermeasures of Economic Development in China's Ethnic Minority Regions. *Mod. Econ. Inf.* **2020**, *3*, 186–187.
10. Jing, C.M. Status Quo of Income Gap in Western Ethnic Area and Strategy Analysis. *J. Northwest Univ. Natl.* **2005**, *6*, 80–86.
11. Li, J.J. A Case Study of Economic Disparity in Ethnic Autonomous Regions and Its Countermeasures. *J. Cent. Univ. Natl.* **2008**, *1*, 14–24. [CrossRef]
12. Gao, Z.G.; Liu, W. Regional Economic Differences and Coordinated Development in Northwest Minority Areas: Taking Xinjiang as an Example. *Nankai J.* **2016**, *3*, 147–160.
13. Dai, M.; Wang, P.; Li, Y.X. Analysis of Economic Disparities and Influencing Factors in Northwest Minority Regions. *Financ. Account. Mon.* **2017**, *12*, 108–113. [CrossRef]
14. Zheng, C.D. A Study on the "Five Development Concepts" and Comprehensive Development of the Social Economy in Ethnic Areas. *J. Ethnol.* **2017**, *8*, 1–21, 94–97. [CrossRef]
15. Luo, J.; Zhuang, Z.X. The variation trend of economic development in the ethnic minority regions of southwest borderland since the launch of western development in china—Based on Empirical Studies in Guangxi and Yunnan from 1995 to 2014. *Guangxi Ethn. Stud.* **2017**, *5*, 156–164.
16. Croft, T.A. Nighttime images of the earth from space. *Sci. Am.* **1978**, *239*, 86–98. [CrossRef]
17. Li, D.R.; Li, X. An Overview on Data Mining of Nighttime Light Remote Sensing. *Acta Surv. Mapp.* **2015**, *44*, 591–601. [CrossRef]
18. Elvidge, C.D.; Baugh, K.E.; Kihn, E.A.; Kroehl, H.W.; Davis, E.R.; Davis, C.W. Relation between satellite observed visible-near infrared emissions, population, economic activity and electric power consumption. *Int. J. Remote Sens.* **1997**, *18*, 1373–1379. [CrossRef]
19. Elvidge, C.D.; Baugh, K.E.; Dietz, J.B.; Bland, T.; Sutton, P.C.; Kroehl, H.W. Radiance calibration of DMSP-OLS low-light imaging data of human settlements. *Remote Sens. Environ.* **1999**, *68*, 77–88. [CrossRef]
20. Ghosh, T.; Anderson, S.; Powell, R.L.; Sutton, P.C.; Elvidge, C.D. Estimation of Mexico's informal economy and remittances using nighttime imagery. *Remote Sens.* **2009**, *1*, 418–444. [CrossRef]
21. Li, X.; Xu, H.M.; Chen, X.L.; Li, C. Potential of NPP-VIIRS Nighttime Light Imagery for Modeling the Regional Economy of China. *Remote Sens.* **2013**, *5*, 3057–3081. [CrossRef]
22. Doll, C.H.; Muller, J.P.; Elvidge, C.D. Night-time imagery as a tool for global mapping of socioeconomic parameters and greenhouse gas emissions. *Ambio J. Hum. Environ.* **2000**, *29*, 157–162. [CrossRef]
23. Elvidge, C.D.; Imhoff, M.L.; Baugh, K.E.; Hobson, V.R.; Nelson, I.; Safran, J.; Dietz, J.B.; Tuttle, B.T. Night-time Lights of the World: 1994–1995. *ISPRS J. Photogramm. Remote Sens.* **2001**, *56*, 81–99. [CrossRef]
24. Henderson, M.; Yeh, E.T.; Gong, P.; Elvidge, C.; Baugh, K. Validation of urban boundaries derived from global night-time satellite imagery. *Int. J. Remote Sens.* **2003**, *24*, 595–609. [CrossRef]
25. Henderson, J.V.; Storeygard, A.; Weil, D.N. Measuring Economic Growth from Outer Space. *Am. Econ. Rev.* **2012**, *102*. [CrossRef]
26. Michalopoulos, S.; Papaioannou, E. Pre-colonial Ethnic Institutions and Contemporary African Development. *Econom. J. Econom. Soc.* **2013**, *81*, 113–152. [CrossRef]
27. Wu, J.S.; Wang, Z.; Li, W.F.; Peng, J. Exploring factors affecting the relationship between light consumption and GDP based on DMSP/OLS nighttime satellite imagery. *Remote Sens. Environ.* **2013**, *134*, 111–119. [CrossRef]
28. Jiang, W.; He, G.J.; Liu, H.C. Modelling Regional Socio-economic Parameters Based on Comparison of NPP/VIIRS and DMSP/OLS Nighttime Light Imagery. *Remote Sens. Inf.* **2016**, *31*, 28–34.
29. Zhu, H.; Zhang, Q.L.; Zhang, S. Analysis of the temporal and spatial characteristics of social and economic development in Central Asia based on night-time light remote sensing from 1992 to 2017. *J. Geo-Inf. Sci.* **2020**, *22*, 1449–1462. [CrossRef]
30. Li, G.E.; Cai, Z.L.; Liu, X.J.; Liu, J.; Su, S.L. A comparison of machine learning approaches for identifying high-poverty counties: Robust features of DMSP/OLS night-time light imagery. *Int. J. Remote Sens.* **2019**, *40*, 5716–5736. [CrossRef]

31. Andreano, M.S.; Benedetti, R.; Piersimoni, F.; Savio, G. Mapping Poverty of Latin American and Caribbean Countries from Heaven through Night-Light Satellite Images. *Soc. Indic. Res.* **2020**, 1–30. [CrossRef]
32. Pokhriyal, N.; Jacques, D.C. Combining disparate data sources for improved poverty prediction and mapping. *Proc. Natl. Acad. Sci. USA* **2017**, *114*. [CrossRef] [PubMed]
33. Li, G.E.; Cai, Z.L.; Liu, J.; Liu, X.J.; Su, S.L.; Huang, X.R.; Li, B.Z. Multidimensional Poverty in Rural China: Indicators, Spatiotemporal Patterns and Applications. *Soc. Indic. Res.* **2019**, *144*. [CrossRef]
34. Donald, H.; Thomas, K.; Thomas, L.; Daniel, L.; Curtis, S.; Steven, M.; Jeremy, S.; Stanley, K.; Scott, B.; Tommy, J.; et al. First-light imagery from Suomi NPP VIIRS. *Bull. Am. Meteorol. Soc.* **2013**, *94*, 1019–1029. [CrossRef]
35. Jing, X.; Shao, X.; Cao, C.Y.; Fu, X.D.; Yan, L. Comparison between the Suomi-NPP Day-Night Band and DMSP-OLS for Correlating Socio-Economic Variables at the Provincial Level in China. *Remote Sens.* **2015**, *8*, 17. [CrossRef]
36. Elvidge, C.D.; Zhizhin, M.; Baugh, K.; Hsu, F.C. Automatic boat identification system for VIIRS low light imaging data. *Remote Sens.* **2015**, *7*, 3020–3036. [CrossRef]
37. Fox, H.S.A.; Gelling, M. "book-review" Signposts to the past. Place-Names and the History of England. *Geogr. Rev.* **1981**, *71*, 231. [CrossRef]
38. Chu, Y.; Yin, J.; Sun, D. *Basic Tutorial of Toponyms*; Surveying and Mapping Press: Beijing, China, 2009.
39. Conedera, M.; Vassere, S.; Neff, C.; Meurer, M.; Krebs, P. Using toponymy to reconstruct past land use: Acase study of 'brusada' (burn) in southern Switzerland. *J. Hist. Geogr.* **2007**, *33*, 729–748. [CrossRef]
40. Jett, S.C. Place-Naming, Environment, and Perception among the Canyon De Chelly Navajo of Arizona. *Prof. Geogr.* **1997**, *49*, 481–493. [CrossRef]
41. Evereet-Health, J. *Place Names of the World—Europe*; Palgrave Macmillan: London, UK, 2000.
42. Adrian, R. *Placenames of the World: Origins and Meanings of the Names for 6600 Countries, Cities, Territories, Natural Features and Historic Sites*, 2nd ed.; Choice Reviews Online; McFarland: Jefferson, NC, USA, 2006; Volume 43. [CrossRef]
43. Ray, I. Linguistic Geography of Chinese Dialects. *Cah. Linguist. Asie Orient.* **1995**, *24*, 195–227. [CrossRef]
44. Hartmann, J.F. The Power to Name Places: Ban, Muang, Chiang, Viang, Nakon, Krung. In *Studies in Tai and Southeast Asian Linguistics*; Harris, J., Burusphat, S., Eds.; Ekphimthai Ltd.: Bangkok, Thailand, 2007; pp. 139–154.
45. Xu, Z.N.; Gao, X.L. A novel method for identifying the boundary of urban build-up areas with POI data. *Acta Geogr. Sin.* **2016**, *71*, 928–939. [CrossRef]
46. Liu, Q.Y.; Zhan, Q.M.; Li, J.S.; Yang, C.; Liu, W. Extracting Built-up Areas Using Luojia-1A Nighttime Light Imageries in Wuhan, China. *Geomat. Inf. Sci. Wuhan Univ.* **2021**, *46*, 30–39. [CrossRef]
47. Heidenreich, N.B.; Schindler, A.; Sperlich, S. Bandwidth selection for kernel density estimation:A review of fully automatic selectors. *Adv. Stat. Anal.* **2013**, *97*, 403–433. [CrossRef]
48. Li, F.; Yan, Q.W.; Zou, Y.J.; Liu, B.L. Improving the Accuracy of Built-up Area Extraction Based on Nighttime Light Data and POI: A Case Study of NPP/VIIRS and Luojia 1-01 Nighttime Light Images. *J. Wuhan Univ. Inf. Sci. Ed.* **2019**, *46*, 1–14.
49. Zhao, F.; Ding, J.Y.; Zhang, S.J.; Luan, G.Z.; Song, L.; Peng, Z.Y.; Du, Q.Y.; Xie, Z.Q. Estimating Rural Electric Power Consumption Using NPP-VIIRS Night-Time Light, Toponym and POI Data in Ethnic Minority Areas of China. *Remote Sens.* **2020**, *12*, 2836. [CrossRef]
50. Zhou, Z.H.; You, R.J. *Dialects and Chinese Culture*; Shanghai People's Publishing House: Shanghai, China, 1986; pp. 7–9.
51. Liu, Y.H.; Xu, Y. Geographical Identification and Type Classification of Multidimensional Poverty in Rural China. *Acta Geogr. Sin.* **2015**, *70*, 993–1007. [CrossRef]
52. Zhang, E.M.; Deng, J.; Song, X.J.; Dai, K.R.; Shi, X.L. Multi-dimensional poverty identification and evolution analysis based on night-time light data. *Hubei Agric. Sci.* **2019**, *58*, 126–133. [CrossRef]
53. Shen, D.; Zhou, L.; Wang, P.A. Analysis of Poverty Spatial Differentiation Characteristics in Liupanshan Contiguous Destitute Area Based on Night Light Data. *Remote Sens. Inf.* **2018**, *33*, 42–48. [CrossRef]
54. Zhang, J.Q.; Wu, Y.J.; Ge, Y.; Wang, C.H.; Kung, H. Comprehensive Evaluation of Ecological Security in Poor Areas Based on Grey Relational Model—Taking Enshi Poor Area as an Example. *Geogr. Res.* **2014**, *33*, 1457–1466. [CrossRef]
55. Wen, K.Z. Thoughts on the Protection and Development of Ethnic Minority Culture. *J. Guangdong Inst. Social.* **2007**, *28*, 49–54.